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PROCEEDINGS:

WEED CONTROL TRAINING SESSIONS

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-F O R E W A R D-

Weed control has been a long-standing controversial practice. Numerous legitimate concerns and adverse effects on human health and the environment resulting from the application of herbicides and control of weeds have been observed. At the same time, the limiting effect of weeds on crop yields, quality and production costs are recognized to be a major hindrance to agricultural production.

The science of weed control is advancing at a rapid pace, making it difficult for persons in the field to keep abreast of new developments. Today, governmental agencies and the public are demanding that programs in weed control encompass the objectives of environmental protection, as well as agricultural improvement. These demands require full utilization of all available tools for weed control with consideration in their selection given to human health and safety, environmental protection and effective weed control.

It was the purpose of these weed control training sessions to bring together as a whole these aspects of weed control and provide possible solutions to assist ongoing weed control programs in evaluating and developing program objectives.

This manual is made available to participants of the weed control training sessions. Additional copies are available upon request from the State Department of Health and Environmental Sciences. We sincerely hope this manual will be of value in future weed control operations and will assist weed control programs in attaining a common goal of adequate protection of human health and of the environment.

The Department of Health and Environmental Sciences wishes to extend its thanks and appreciation to the faculty for making possible the training sessions and this manual.

Preparation of this proceedings was made financially possible through Federal Contract No. RFP DU-72-B900, Division of Pesticide Community Studies, Environmental Protection Agency.

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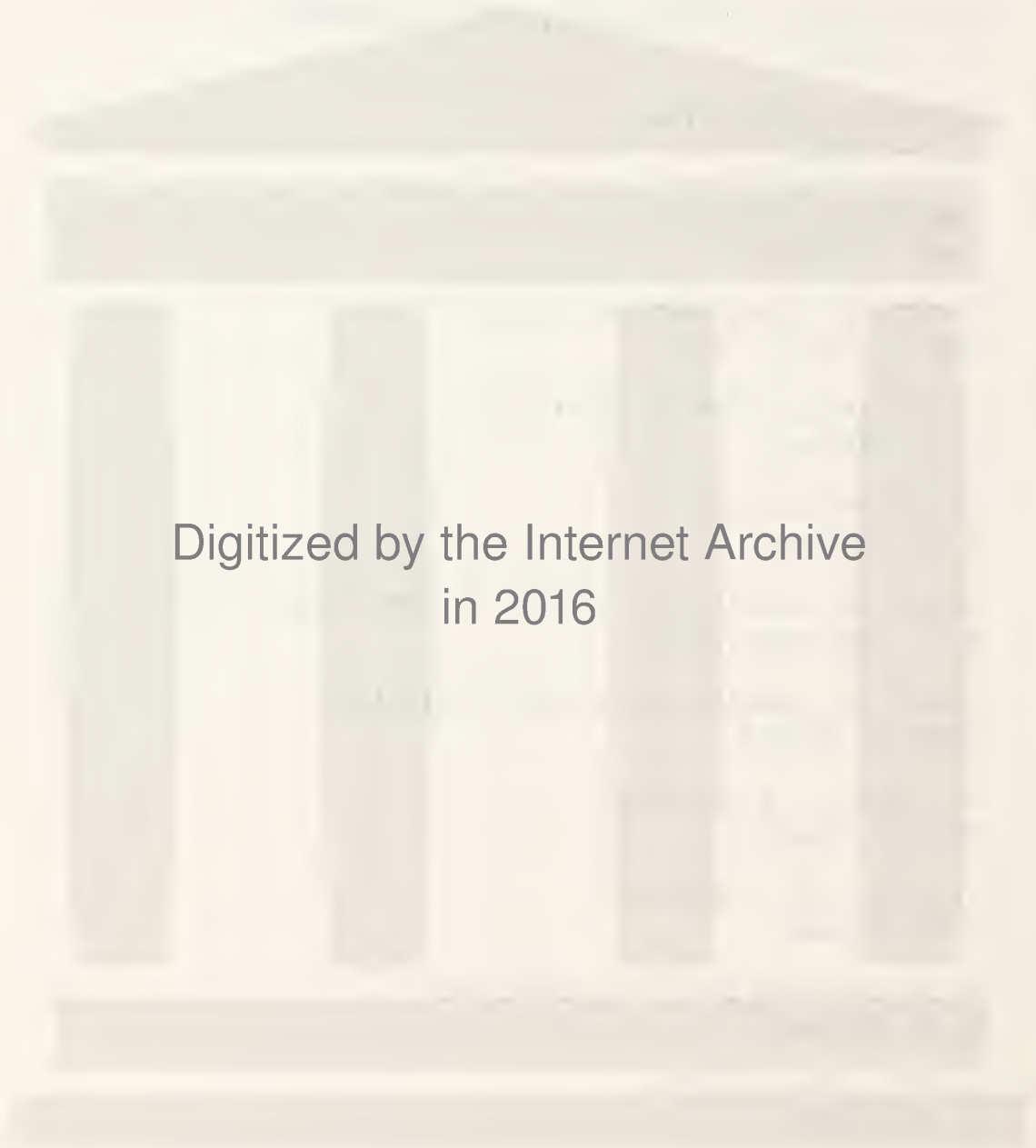

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A. EFFECTS OF HERBICIDES ON WILDLIFE
Eldon Smith

B. AERIAL APPLICATION
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Presented at
Montana Herbicide Workshops
Oct. 12-20, 1972

INTERACTIONS OF HERBICIDES IN THE ENVIRONMENT

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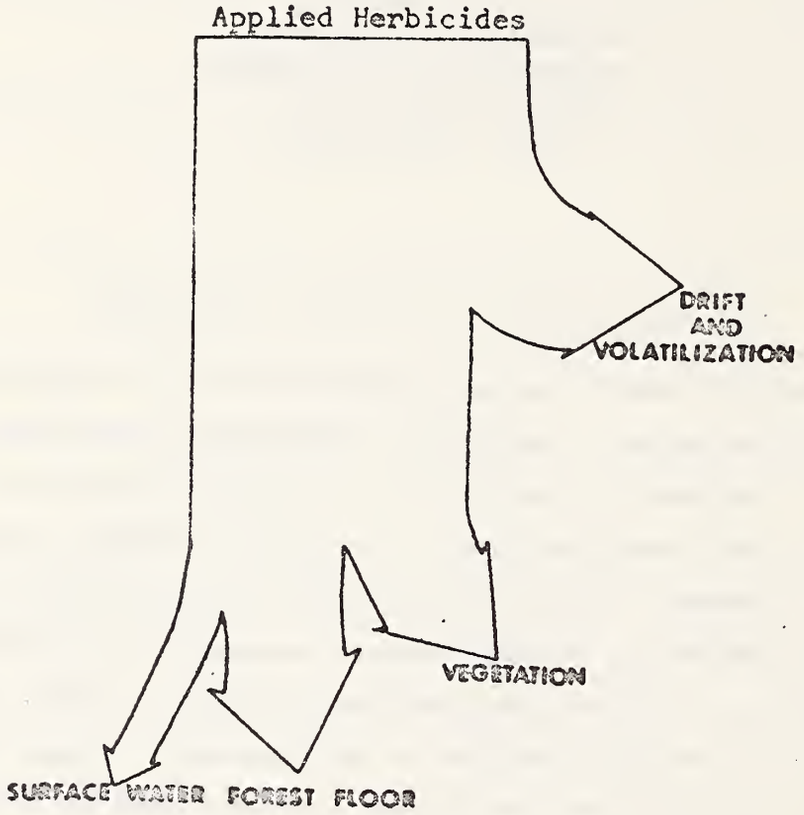
THE DISTRIBUTION OF APPLIED HERBICIDES

Herbicides with very diverse characteristics are applied by various methods for a wide range of vegetation management objectives in crop and non-crop uses. We need to know as much as possible about the fate of these chemicals and possible effects from them on areas or plants not intended for treatment. Fortunately, before any herbicide or agricultural chemical can be marketed, it must undergo extensive evaluations regarding possible effects on various large and small animals, birds, fish and soil organisms, and the residual nature of the compound. These studies require 4 to 6 years to complete and are extensively reviewed by EPA and Sports Fisheries and Wildlife before registration. We can use some of these data to predict possible effects of herbicides on non-target organisms. We do not and never will have all the answers but the results of field and laboratory testing already accumulated enable us to use herbicides effectively without adverse effects on the environment.

All applied herbicides are distributed among the various portions of the environment--the air, the target or other plants and other organisms, water (both open and ground) and the soil--as portrayed in Fig. 1. The relative amounts of herbicide in each of these elements will depend on the rate applied, volume rate, particle size, formulation (spray or granular), the vegetation--types and amount--weather conditions, soil type, slope and cover, and types and proximity of water bodies. Of course, the distribution will change with with time and the herbicides will ultimately disappear entirely. It is fortunate that all of the existing herbicides are organic molecules that decompose

FIGURE 1

Distribution of Applied Herbicides



--From Norris

or disappear by dilution below the level of detection, chemical degradation or reaction, metabolism by plants or animals, microorganism degradation, photodegradation (sunlight) and heat. Only one group--the arsonates--decompose into materials that retain some toxicity to fowl, animals or fish.

There is a difference in the manner and time required for various herbicides to disappear; the rate of disappearance depends on a large number of influences. The most important of these are the chemical structure, the formulation, location of the compound in the environment, moisture and temperature of the surrounding medium, exposure to leaching or run-off, photoreaction, soil factors such as texture, pH, organic matter, and type of minerals. I will have time to relate only a few of the most commonly used herbicides to the effects of these factors. I believe the characteristics

of any particular herbicide product can be reviewed in the WSSA Weed Manual, Montana Weed Control Manual and other such references and allow a reasonable prediction of the manner in which the herbicide will act in the environment. I will discuss herbicidal activity or selectivity only very briefly. I hope to give you a basis for evaluating the nature of the product to be applied with respect to its effects on and life in various elements in the treated plots, as well as the surrounding areas.

To establish a common base of understanding, we need to categorize the herbicides according to their method of action.

1. CONTACT - Not translocated - Kills tissue directly contacted by the herbicide.

2. SYSTEMIC - Translocated within the plant to other plant parts by
   a. Foliar Absorption
   b. Soil Absorption
   c. Both

A number of common herbicides and their mode of entry or herbicidal action in plants are listed in Table 1.

Several references will show the nature of any given compound or formulation. It will be increasingly important to know what you are handling. Nearly all the herbicides applied as granules will reach the soil surface directly. Sprays will be intercepted by foliage or stems in proportion to the canopy. Some herbicides in fields may be incorporated into the soil immediately by machine or rain.

The spray on plants can react with leaf cells to effect a burn, be absorbed and translocated, remain on leaf surface unreactive or be washed off if rain occurs, as shown in Fig. 2. The material on the leaf surface can remain unchanged, volatize off or be degraded by sunlight, usually requiring a little moisture. Most herbicides are subject to more or less attack by sunlight and may be completely inactivated (Crosby). Herbicide

TABLE 1. Phytotoxic Action of Several Herbicides

Compound	Type of Action
2,4-D amines & esters	Foliar systemic - Broadleaf weeds & brush
2,4,5-T amines & esters	" " - Brush
Silvex amines & esters	" " - Some broadleaf weeds & brush
2,3,6-TBA	Soil absorption, some foliar systemic.
dicamba	Foliar & soil systemic.
Fenac	Soil sterilant - Systemic.
Picloram - Salts & esters	Foliar & soil systemic - perennial broadleaf weeds and woody plants.
Atrazine	Soil & foliar systemic action - Perennial grasses & annual broadleaf weeds
Simazine	Soil systemic - Annual weeds.
Diuron	Soil systemic - Annual weeds.
Linuron	Soil & foliar systemic - Annual weeds.
Bromacil	Soil and foliar systemic - Perennial grasses and annual weeds.
Dinoseb (DNBP)	Contact & soil - Annual weeds.
Paraquat	Contact only - Annual weeds, mostly grasses.
STCA	Soil systemic - Grass killer.
Dalapon	Foliar systemic - Grass killer.
Trifluralin (Treflan)	Soil systemic.
MSMA or DSMA (arsonate)	Certain perennial grasses & nutgrass. Contact
Oils	Contact - Creeping action

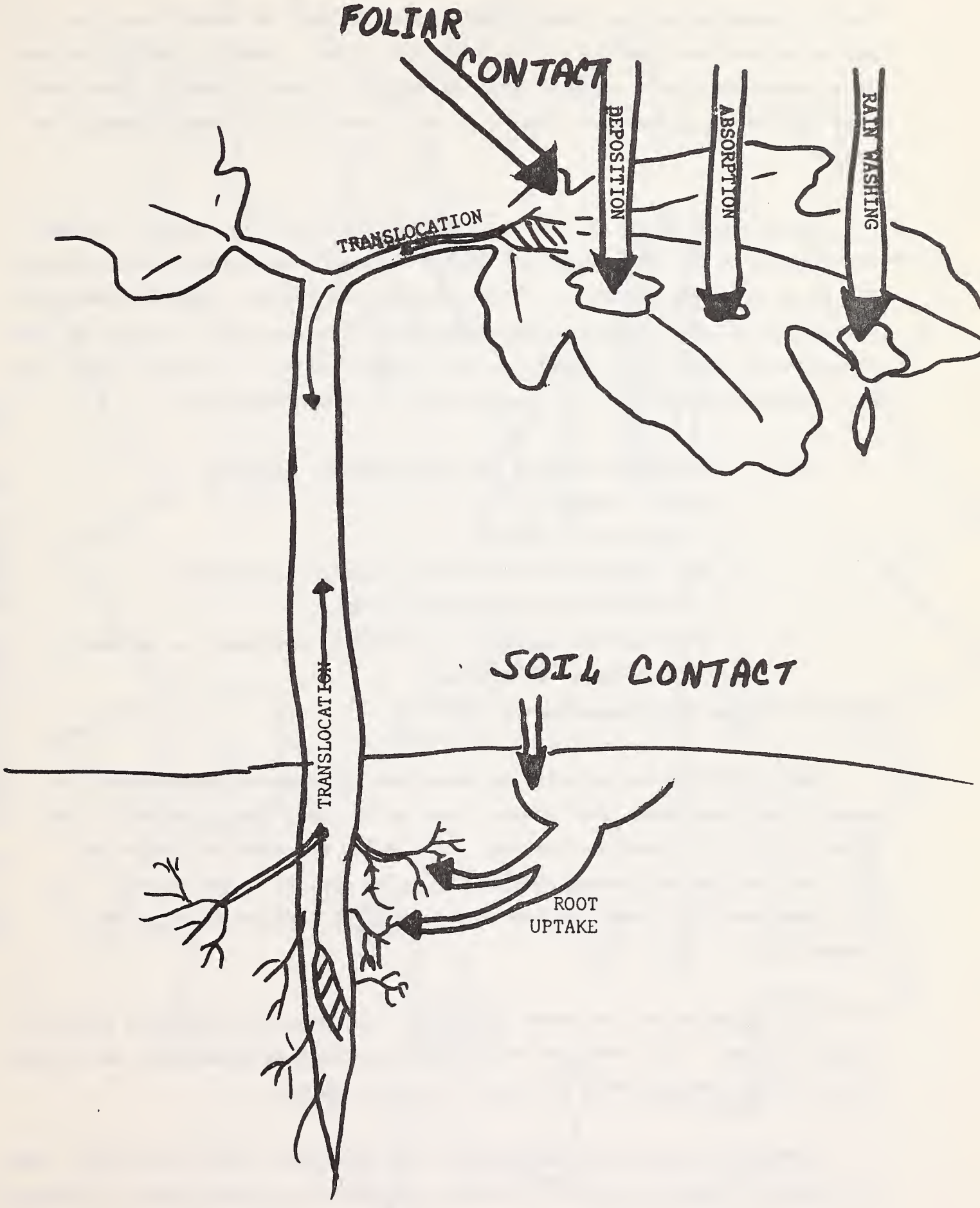


FIGURE 2

Dispersal of Herbicides on Plants and Soil

that is absorbed can be translocated or remain near the absorption site. It may be metabolized readily or slowly by the plant. Usually plants that are less susceptible to a compound will metabolize it more quickly. Some herbicide may remain in treated plants, in small amounts, for several months or longer.

Certain herbicides will move by translocation to the roots; they may be released to the soil either by direct leakage from the rootlets or death and decay of these rootlets. The herbicide then becomes available for root absorption by other plants whose roots occupy the same space, either at the same time or later. The herbicide that washes off or is in plant parts that fall become part of the soil complex which is considered below.

After the herbicide reaches the soil surface, it may:

1. Remain unmoved.
2. Volatize into the air.
3. Be leached into the soil by rain or irrigation.
4. Be carried away in run-off water.
5. Move on soil particles by erosion, equipment or animals.
6. Be decomposed by sunlight.

These functions are diagrammed in Fig. 3.

Herbicides can be degraded or leave the target area undecomposed by some of the same means plus others, such as in food, feed or animals, as shown in Fig. 4. These actions may occur under the same influence and will be discussed as general principles to be applied appropriately. We will consider first those actions that result in disappearance on the treated site.

Photodegradation can occur as soon as the herbicide reaches a solid or liquid surface. This reaction will occur only in direct sunlight and usually only in clear water. This is usually a fast reaction.

Burning or just high temperatures will decompose most herbicides. Work by chemical disposal experts indicates that nearly all pesticides will degrade

FIGURE 3

FATE OF HERBICIDES AFTER REACHING THE SOIL

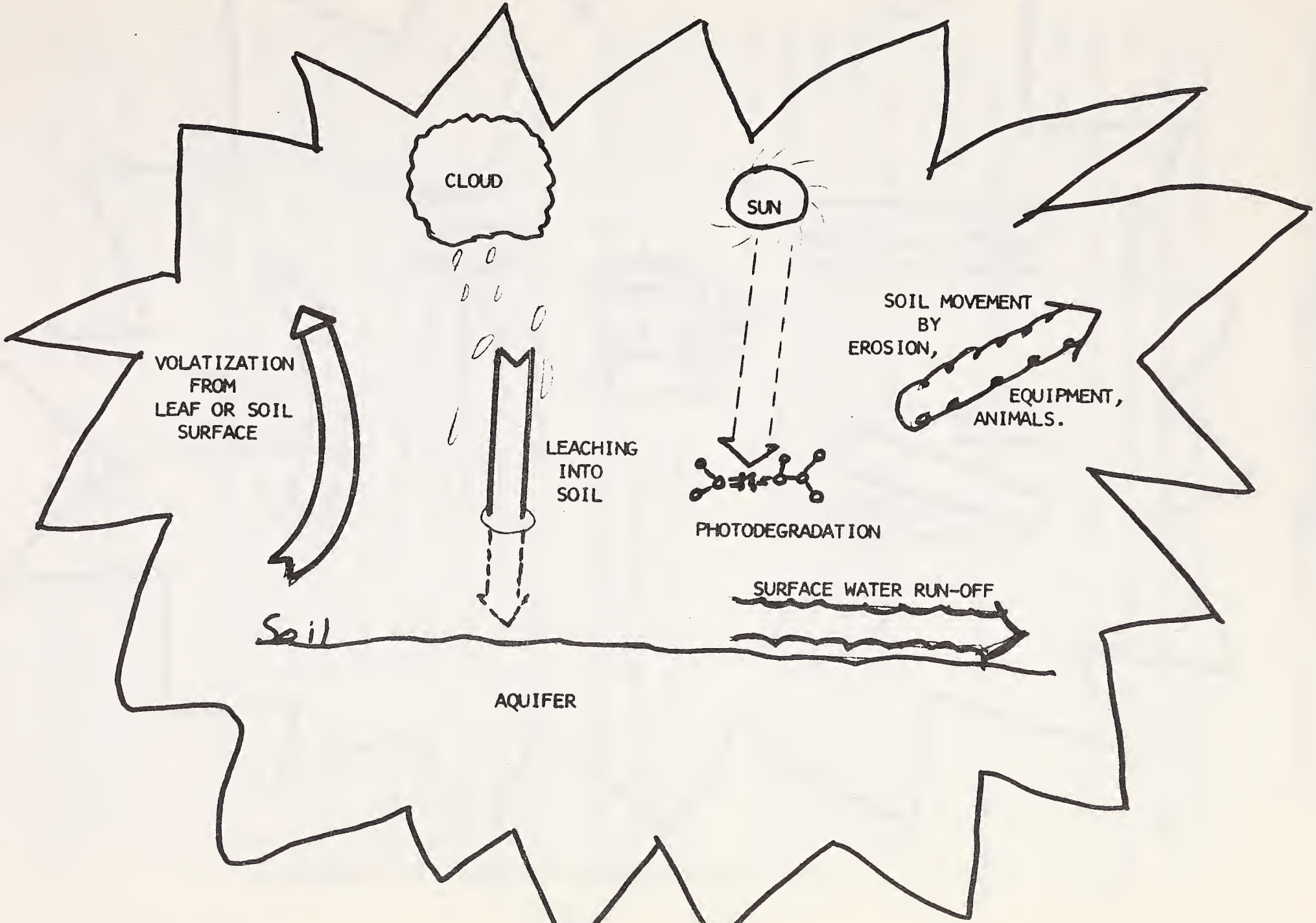
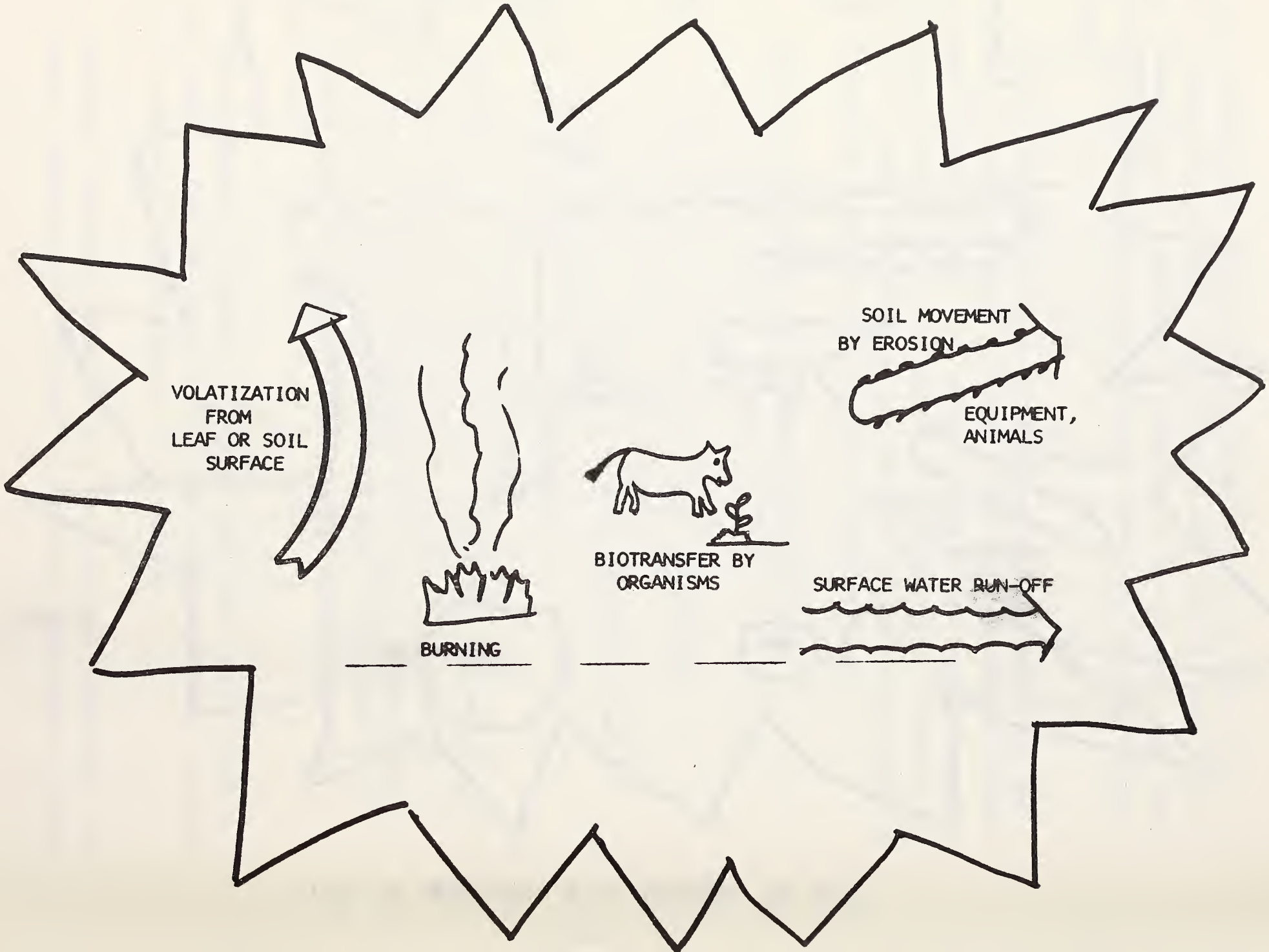


FIGURE 4

MOVEMENT OF HERBICIDES FROM TREATED SITE



at temperatures of 600 to 700°F for an hour or more. In the environment, burning treated areas can reduce herbicides in the forage or soil zones. Some burns on plots treated with picloram had about half as much as unburned plots. The kindling temperatures of the fuel must reach the herbicide breakdown level.

Volatilization will be discussed later. It may or may not cause damage to off-target plants.

Herbicides move into and through soils under the influence of water, except for deliberate incorporation and very minor other forces. The factors that influence this movement are water solubility, and sorption characteristics of the herbicide, and the soil texture, structure, mineral type, pH, organic matter and moisture.

Two important facts should be remembered about the amount of leaching of herbicides into and through soil -- The herbicide will move only with and in the direction of a water flux and Time is required for sorption to occur.

Except for some sorption to surface litter, water solubility and soil moisture content at the surface are responsible for the amount of herbicides that enter the soil. The more soluble materials will enter the soil more readily under leaching. Since the water must move through channels in the soil, the amount of water at and near the surface will affect surface water movement and consequently the amount of herbicide entering the soil. If the soil were wet to the surface at the time of application and rain falls soon afterward, the rain water will run off probably carrying some herbicide with it. If the surface is dry at the time of application or if rain delays until the soil surface is dry, rain falling after that will take much more herbicide into the soil.

These same factors regulate the degree of movement through the soil, but soil texture, structures and sorption potential become very important. Soil texture will usually have a direct effect on chemicals moving in water

through the soil; finer soils have more adsorbing surface and the water flux is slower. Sorption is usually greater at lower pH, but may not be very pH sensitive in higher organic matter and in finer soils.

Certain compounds, such as diuron, react with organic matter and are deactivated. Usually there is considerable sorption of herbicides on organic matter without deactivation. In some cases, the rate of release is slow enough that increased rates are needed for weed control. Several herbicides, such as dalapon, TCA and dicamba, are sorbed little if any and are leached readily through the soil. Mineral components of soil vary in their ability to sorb pesticides. Certain clays are more effective than others, but there is some specificity for each herbicide. Herbicides such as 2,4-D, picloram, 2,4,5-T, atrazine, diuron, etc., are adsorbed rather tightly.

The time factor for effective sorption may vary from a few hours to several days. If continuous leaching conditions are imposed on a treated area after application, the herbicide will be moved much deeper than if water to wet ½" to 1" deep is applied and allowed to sit 1-2 days before resuming irrigation. Any movement of moisture upward or horizontally in the soil can carry herbicides in those directions also. Sampling treated areas for depth of herbicides that are sorbed fairly well has shown that even under leaching with comparatively high amounts of rainfall, they remain in the top few feet of soil. Those herbicides that are readily adsorbed or are low in solubility are usually in the top 1 to 2 feet.

Many herbicides undergo reactions with water and/or soil constituents to decompose or otherwise change chemically. Usually these reactions occur over several weeks to months and require favorable temperatures and other soil conditions, such as moisture, pH and mineral components.

The newer herbicides and most of the older ones now have been studied to determine the degradation products, if any, and their nature, amounts and toxicity. The EPA pesticide laws and policies require that all such products have to be identified and shown to be present in minute or insignificant amounts for Federal registration. It can be assumed that any degradation or reaction products of herbicides in the environment do not constitute a hazard of any nature. This assumes, of course, that the products are used as

specified on the labels. Herbicides that degrade chemically include dalapon, dinoseb, amitrol, dicamba, Eptam, prophram, etc.

Herbicides are usually metabolized by plants and animals but the rate varies tremendously. Plants that can metabolize certain herbicides readily are usually not affected as much as those that do not cause much decomposition. This relationship is not general however; picloram will enter grass plants and remain essentially undecomposed even though the grass is tolerant. Practically, the mode and degree of metabolism by plants and animals is unimportant since crops for food or feed have tolerances for residues that are found; the herbicides are low or very low in toxicity and animals eliminate the compounds in a day or two many times with little change.

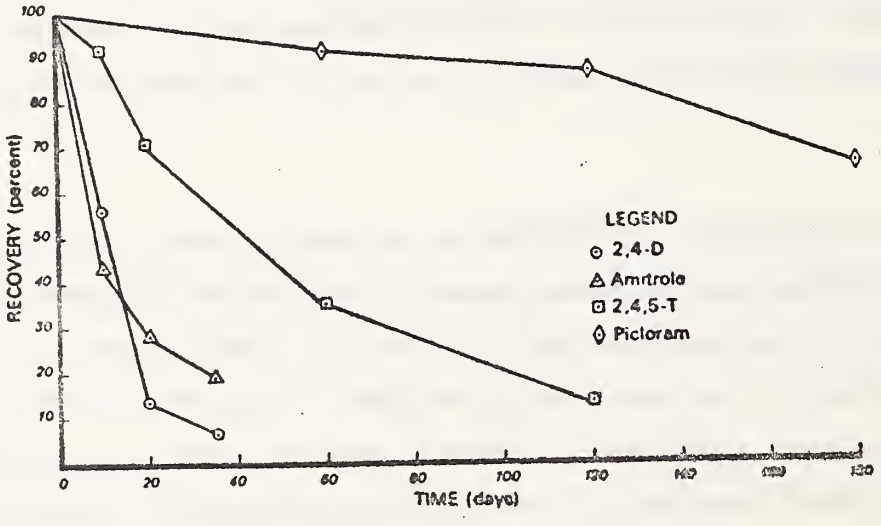
Decomposition of herbicides by microorganisms in the soil is probably the most general and reliable means of herbicide disappearance from the environment after application. All organic herbicides in soil are subject to this attack. Certain groups are more effective on certain herbicides but they all are dependent on favorable conditions for activity, which include good soil moisture, favorable temperature, pH and salts.

Several herbicides will supply a main source of carbon energy for microorganisms; they will be decomposed faster the second time of application. Dalapon, 2,4-D, dinoseb, TCA and diuron are examples. Most herbicides are decomposed incidentally as they are ingested by microorganisms. They do not disappear faster with succeeding applications. Examples are 2,4,5-T, silvex, picloram, chlorinated benzoic acids, atrazine, bromacil, etc. Within this group, rates of decomposition vary from a few weeks for 2,4,5-T to several years for picloram and bromacil. The effect favorable soil conditions can have on herbicide disappearance is demonstrated by the loss of picloram in Texas vs. Montana. Picloram at 2 lbs. per acre in eastern Texas will disappear in 8-12 months, whereas ½ lb. per acre in Montana may persist for 2-4 years.

Fig. 5 demonstrates the rate of loss of four foliar active herbicides from the forest floor as determined by Norris. 2,4-D and amitrole were lost in about 30 days; 2,4,5-T required another month and picloram remained at 65% of the original level after 180 days. The residual life in the soil of several herbicides was estimated by Sheets and his co-workers as presented in Table 2.

FIGURE 5

Recovery of 2,4-D, 2,4,5-T, amitrole and picloram from red alder forest floor material



--From Norris, 1970

I referred earlier to water quality in connection with herbicide use. Most aquatic herbicides are comparatively toxic to aquatic life and techniques must be observed to avoid problems in this area. The herbicides used for ditchbank weed control are fairly low in mammalian toxicity, but the oil-soluble forms may hurt aquatic life. The major objective with careful application is to prevent contamination of water with herbicides that could hurt desirable plants. Bruns, Hodgeson, Comes and Arle have investigated several herbicides that may be used along irrigation canals or ditches and found that amounts that would injure most crops or plants are unlikely to occur. Care must be observed to use only those products that have been tested in these uses. Of course, certain waters must meet FWQA standards and care is needed to prevent detectable residues of herbicides

TABLE 2. Persistence of Various Herbicides in Soil

Herbicide	Lb./Acre	Residual Phyto-toxicity (months)[1/]
Amitrole	3-18	1-3
Atrazine	2-4	4-7
Diuron	3.6-4	5-7
Fenac	4-5	12
Monuron	2-4	5-8
Endothall	6	1
Simazine	2-5	12
Dalapon	6-20	1
2,4-D	1-5	1
2,4,5-T	1-5	3-6
Silvex	1-5	4-7
TCA	12.5-67	7-12
Picloram	0.5-1	6-12
2,3,6-TBA	15-20	12-32

[1/] Under conditions favorable for growth.

--Sheets, 1972
(Mullison, DTE, Fall, 1972)

for which tolerances are not set. Hopefully some of these herbicides can be cleared for use on waterways.

There is some evidence that soil condition could be affected directly by high rates of certain herbicides, such as chlorates and borates, although repeated weed control practices could change structure and possibly pH and organic matter. At rates of most herbicides presently in use, there appears to be little if any effect on soil condition.

Movement of herbicides off the target or directly treated area is an important consideration in the application. It may result in problems that could be monumental. These can include adverse or beneficial effects on

plants, adverse effects on animals consuming plants, residual or carryover effects on seeds or transplants, residual effects on succeeding crop or invading roots, water quality, illegal residues on crops, or miscellaneous spotting. There is need to analyze these possibilities. How can herbicides move off the target and what influences these actions?

Movement of a herbicide in run-off water is affected by water solubility and sorption characteristics but the latter is less important than in the soil volume. Other factors include the vegetation type and density, soil type (surface), condition and slope and rainfall intensity and nature. Vegetation actually affects the amount of rain needed to produce run-off. On a bare sloping surface, such as a roadside, a small amount of rain can move the herbicide downslope, produce run off, whereas on a good grassy surface, very little run-off would occur with a rather heavy rain. Some dry soils, especially after a burn, tend to seal over and long wetting periods are required to restore water transmission. If the surface soil is nearly saturated, most water falling there will run off. The effects of rainfall intensity and nature on run-off are apparent; a hard rain is more likely to produce run-off than a gentle rain for a longer period.

Soil residues that may affect a succeeding crop can be important. We may consider a crop planted after one being treated to have non-target plants. The possibility of residual effects on such subsequent crops is an important consideration. You may use atrazine on corn unless soybeans will follow. Care is needed in trifluralin use with certain rotations. Karmex on grain will cause residual effect for 6-12 months. It is also very possible for off-target plant damage to occur from pick up by roots invading the treated area or zones of run-off. Peach roots reached under a county road to get to a soil sterilant in California.

Range watersheds providing water for crop areas may present run-off hazards to crops using that water. Experiments and monitoring run-off water for herbicides from treated watersheds indicates that very small amounts of the herbicide come off in the first water that leaves the site

after application of sprays. Depending on the time to the next storm, there may be some more in succeeding run-offs, but it is nearly always less with time. Results of studies in Arizona and elsewhere indicate that adsorption or other reactions usually removes herbicides from water running over untreated watershed surfaces or in streams. Where known amounts of picloram were placed in streams and samples collected downstream, it was detectable for only 1 to 2 miles. Also, where it was in running water at the outflow of a watershed in Utah at ¼ to 2 ppm, it became undetectable 100 to 1,000 meters downstream. The same results were obtained with 2,4-D and 2,4,5-T on similar watersheds. As a result of these and many other studies, Norris (U.S. Forest and Range Experiment Station, Corvallis, Oregon) has concluded that if herbicides applied by air to range and forest sites are not actually placed in streams or lakes on the site, there will be no detectable amounts in the water. Herbicides applied to dry irrigation ditches can move into crops at injurious levels.

Another means of moving chemicals from a treated site is by animals, fowl or aquatic life either by direct exposure or ingestion of treated forage or contaminated water. Nearly all herbicides will pass through these organisms with little change or retention. Excrement containing the herbicide may be deposited where damage to plants could occur. Care should be taken to be sure animals grazing treated areas will not move to fields where crops sensitive to the herbicide may be grown until all the chemical has cleared through the animals.

Soil microorganisms vary greatly in their characteristics and therefore susceptibility to direct effects of herbicides. Very few herbicides will greatly affect all microorganisms even if they are fairly toxic, e.g., dinoseb is a general biocide and is known to control certain soil fungi, but is decomposed by certain microorganisms that use it as a source of energy. Responses of several groups of soil organisms are not seriously affected by rates of use needed for weed control. There may, however, be temporary changes in the microorganism spectrum.

With certain precautions in selection of the proper herbicide and rate of use and care in application, undesirable side-effects should be slight. The instructions on labels and in herbicide handbooks regarding proper rates, application methods and times should be adequate. Special attention should be given to drift, volatility and run-off problems and to the possibility of residual effects if plans include planting crops or plants in the treated area. Drift and volatility problems will be discussed later. Where residues in soil are likely to be undesirable, steps can be taken to induce fastest possible disappearance. These include keeping the area moist during the warmer parts of the year, incorporation, planting tolerant crops. Sometimes lower herbicide rates along with competition from certain tolerant plants will give good weed control; this will reduce residual effect. Of course, a less residual or more selective herbicide could be used.

With residual herbicides, care should be taken to prevent moving soil from the treated area or grazing animals there and transferring them to fields where susceptible crops are or will be planted.

The potential for contaminating irrigation or potable water supplies through pick up in run-off water or from treating canal or irrigation ditch banks should be assessed carefully. Usually a review of the paths run-off water would take is sufficient to prevent problems.

In conclusion, careful consideration of the objectives for a particular herbicide use, the nature of the herbicide, the conditions in the target area, and projected use of the area will enhance benefits from these tools. Organic herbicides have been used in the last 30 years with great success in improving many aspects of the environment. They present very little hazard to animal life generally, but must be carefully regulated around plants to achieve the desired effects. The herbicides in use are all organic molecules and they decompose in relatively short times by several processes. They do not accumulate in soil or food chains when used according to label recommendations, and have no harmful effects on soil. As with most tools, good judgement in the uses of herbicides will allow treating the croplands and ranges to derive the benefits with minimum adverse environmental effects.

PESTICIDE LEGISLATION

Robert LaRue

The Montana Pesticides Act as passed by the 43rd legislature became effective January 1, 1972. This act controls the distribution, sale, application, disposal and transportation of pesticides and devices; creates a temporary advisory committee, provides for the registration of pesticides and licensing of applicators. It also provides for administrative appeals and civil penalties.

The control of pesticides and their use is essential for the protection of man and his environment. However, pesticides are currently considered valuable and necessary to provide sufficient quantities of quality foods and for the protection of humans from vector-borne diseases.

The Montana Pesticides Act is administered by the Pesticides Control Division of the Montana Department of Agriculture.

The Montana Pesticides Act provides for the licensing of commercial pesticide applicators, for the licensing of pesticide dealers and retailers, and for the registration of all pesticide formulations offered for sale in the state of Montana. Most of the work experienced in 1972 has been in these three areas.

One of the licensing requirements for commercial pesticide applicators and pesticide dealers is that they must pass an examination prior to licensing. A temporary study guide was prepared by personnel from the Pesticides Control Division to assist applicators and dealers with their examinations. During the spring of 1972 personnel from this division traveled over 10,000 miles and held 40 examination sessions. These sessions were held in 19 locations

around the state. As a result of these examinations we have licensed 563 commercial applicators, 296 dealers and 739 retailers. Retailers are not required to pass an examination prior to licensing.

Refer to table Number I, entitled LICENSES ISSUED IN 1972. The figures on this table will give you the number of licenses issued for the past year. The figures under commercial applicators are the total number of different types of applicators. On the right of the table you will see a column labeled ANTICIPATED. This column represents the number of commercial applicators, dealers, retailers, and the number of pesticide registrations that we are anticipating to have licensed or registered within the state of Montana by July 1, 1974. The last column under ANTICIPATED illustrates that there are approximately 2,000 pesticide equipment operators. We have a large number of commercial pesticide applicators and pesticide dealers within the state of Montana.

Refer to table Number II, entitled AVERAGES OF PESTICIDE EXAMINATIONS. On the left side of the table is a column marked Specific Examinations. You will find under this column the types of examinations which were given. In the middle of the table are the types of applicators. In the vertical column under the types of applicators are the averages of examinations which were taken. At the bottom of the column there is an average for all examinations taken in that column. On the right of the table there is an average for each specific examination taken by all applicators. At the bottom of the page you will find an average of 77.0 for pesticide dealers. You can determine the averages of examinations by the different types of applicators with the use of this table. As you can see by examining the columns, there is a great difference for the averages received on certain exams by different types of

applicators.

Table Number III includes the Range and the Median for the pesticide examinations. The range includes all grades received from the lowest score to the highest. The median (which is the number included in parenthesis) is the numerical figure halfway between the low and the high scores.

For the year starting January 1, 1973 only those that received a temporary license and those that received extremely low scores on their pesticide examination in 1972 will be required to take the pesticide examinations. The Pesticide Division is currently cooperating with the Extension Service at Montana State University in an attempt to develop training courses and a study guide for commercial applicators and pesticide dealers. These sessions will be terminated with an examination session for those people who need to pass the required examination. We will require an examination from all applicators and dealers every three to four years.

I am sure that many of you are concerned about some of the provisions of the Montana Pesticides Act. One of these areas is liability. Regulations will be developed by public hearing on the requirements for liability for commercial pesticide applicators by January 1, 1974. However, there will be no Surety Bond or Insurance Policy required prior to licensing for 1973.

We may be developing regulations for special permits for farm applicators, regulations for the revocation of licenses and permits, for the disposal of toxic materials and their containers, and for the operation and maintenance of equipment used by applicators. We may also establish methods of record keeping for applicators, operators, dealers and retailers and provide for the review of records by the Department of Agriculture.

Recently the Congress of the United States passed the Federal Environmental Pesticide Control Act of 1972. In addition to providing for the registration

of all pesticides with the federal government, this act requires that pesticide applicators and establishments be registered with the federal government. Applicators will be required to pass comprehensive examinations prior to licensing. These examinations will be given in conjunction with training sessions given by the Extension Service. The state of Montana is required to submit to the Environmental Protection Agency its program for the licensing of commercial applicators and dealers. If this program meets federal requirements, the state may receive federal funds to administer the state law in conjunction with the federal law.

TABLE I

DEPARTMENT OF AGRICULTURE

Pesticides Control Division

LICENSES ISSUED IN 1972

		Actual	Anticipated
1.	Commercial Applicators	563	1,200
	a. Custom 91		
	b. Weed 74		
	c. Seed 158		
	d. Ornamentals 37		
	e. Aerial 106		
	f. Misc. 97		
2.	Pesticide Dealers	296	500
3.	Pesticide Retailers	739	2,500
4.	Pesticide Registrations	1,512	3,000
5.	Pesticide Equipment Operators		2,000

TABLE II

DEPARTMENT OF AGRICULTURE

Pesticides Control Division

PESTICIDE EXAMINATION
AVERAGES

SPECIFIC EXAMINATIONS	TYPE OF APPLICATOR						
	AERIAL	CUSTOM	ORNAMENTAL	PCA	WEED DISTRICT	MOSQUITO DISTRICT	AVERAGES
Basic	81.1	73.4	73.2	79.4	70.5	81.9	76.6
Weed	85.2	81.3	82.5	81.2	84.3	84.0	83.1
Insecticide	71.6	66.6	68.6	76.4	65.8	80.7	71.6
Ornamental	66.0	70.5	73.4	80.0	82.5	77.7	75.0
Mosquito	57.4	42.0	56.5	70.8	37.8	85.0	58.2
Livestock	64.0	78.8		81.0		87.0	77.7
Rodent				76.9			76.9
PCA	64.0	71.0		81.8			72.3
Aerial	84.3	74.5					79.4
Aquatic Weed	87.0	81.6					84.3
Averages	73.06	72.07	74.43	78.44	68.18	82.72	

DEALER

77.0

TABLE III

DEPARTMENT OF AGRICULTURE

Pesticides Control Division

Pesticide Examination
Range-Median

SPECIFIC EXAMINATIONS	TYPE OF APPLICATOR					
	AERIAL	CUSTOM	ORNAMENTAL	PCA	WEED DISTRICT	MOSQUITO DISTRICT
Basic	56 - 95 (75.5)	29 - 97 (63.0)	49 - 89 (69)	65 - 92 (78.5)	6 - 93 (49.5)	53 - 96 (75)
Weed	56 - 95 (75.5)	57 - 96 (76.5)	57 - 93 (75)	59 - 89 (74)	48 - 100 (74)	74 - 91 (83)
Insecticide	43 - 95 (69)	20 - 87 (53.5)	22 - 93 (57.5)	50 - 87 (68.5)	30 - 78 (54)	63 - 94 (79)
Ornamental	22 - 85 (53.5)	21 - 92 (56.5)	15 - 93 (54)	60 - 90 (75)		65 - 95 (80)
Mosquito	20 - 96 (58)	42	25 - 80 (52.5)	41 - 75 (58)	13 - 67 (40)	37 - 100 (69)
Livestock	48 - 93 (70.5)	63 - 96 (79.5)		74 - 88 (81)		74 - 100 (87)
Rodent		77 - 88 (82.5)		32 - 95 (63.5)		
PCA		45 - 98 (71.5)	60 - 84 (72)	50 - 93 (71.5)		
Aerial	54 - 100 (77)	62 - 87 (74.5)				
Aquatic Weed	33 - 100 (66.5)	54 - 95 (74.5)				

DEALER

28 - 94
(61)

HERBICIDES AND HEALTH

James J. Boland

We know that a great deal of time and money is invested by industry in the development of a new pesticide. Estimates range from six to ten years from the time a material shows promise as a pesticide product until it is produced for commercial consumption. This development alone can cost in the neighborhood of twelve million dollars. These developmental efforts on the part of industry are often supplemented by government research.

Herbicides, as a class, have accounted for about two times the production of the second place pesticides, which are the insecticide group.

Regardless of the amounts of research involved, keep in mind that the CIDE at the end of any word indicates a material designed to kill -- be it insects, plants fungi, etc., these materials must be treated with respect.

In terms of adverse health effects being caused by herbicides, there is a paucity of information. This lack of information is not necessarily attributed to the assumption that herbicides are that safe, but we may, in fact, not have a handle on actual incidence of herbicide illnesses because of inadequate reporting of these incidents.

For example, a recent study of some forty hospitals in Kentucky with 250 or more beds, showed that the actual incidence of all pesticide illness was approximately seven times what had actually been reported via the Poison Control Center mechanism. The survey was accomplished by actually screening almost two million in and out-patient records. The criteria used to record an incident was that the case was severe enough to require the attention of a physician. The study showed 387 cases meeting this criteria versus 57 cases reported by established mechanisms.

In any discussion of the effects of pesticides on health, the consequences of misuse are generally recognized. This is especially true in the case of the organophosphate (parathion) and organochlorine (endrin) insecticides. The attitudes reflected in a discussion about herbicides were that they are "safe".

This concept no longer is completely valid. In the past few years, this concept has been opened for debate by some herbicides which have received national or international attention because of suspected adverse health effect.

Examples here are "Orange", a combination of 2,4-D and 2,4,5-T, used to defoliate some areas of Vietnam. There are a number of considerations that center around the use of this material and observed effects. It is known that application rates were 12-15 times normal dosage. Also, multiple treatments at these rates were carried out in order to penetrate the different layers of jungle canopy. There is some question about contamination of the basic material with dioxin, consideration should also be given the pre-existing state of medical practice in Vietnam prior to the U.S. involvement.

Another material that has received national attention has been silvex, in Globe, Arizona.

Paraquat is another. A label change was brought about due to the unusual toxicological properties of this material.

These and other products have changed attitudes in government and industry. The change has been brought about because of the realization that we cannot be satisfied with a "no effect" philosophy, if that philosophy is based on a lack of adequate research.

If we accept the premise that "everything affects something", then more research is needed. At this point in time, we don't have absolute, concrete answers, but we do have interesting indications.

The series of slides presented with this talk attempts to show some of the experiences we have had with both the acute and chronic effects of herbicide materials on health. Limited information and statistics are available for loss of time at work and subsequent income caused by the incidents depicted.

As I said, much is unknown. What I hoped to impart was a feeling for the potential impact herbicides may have on health. On the whole, the U.S. record appears good in all areas of pesticide usage. Resting on past laurels is not an excuse for turning away from the future.

Effects of Herbicides on Wildlife*

John T. Harris, Ph.D.

> "The Montana Wildlife Federation considers the Proposed Modification of Montana Weed Law, printed June 1968 by the Montana Weed Control Association to be based on false and dangerous precepts contrary to biological and ecological principles, representative government, sound economics, and plain common sense.
>
> This proposed legislation, declaring 'noxious weeds to be a menace to the public welfare,' would impose inflexible, mandatory weed control and eradication requirements throughout the State of Montana. The requirements would apply to rural and urban, agricultural and non-agricultural, city, county, and state lands. The same provisions would apply to federal lands, with the consent of the agencies involved.
>
> To the Montana Wildlife Federation, the premise that a 'noxious weed,' regardless of who defines it or where it may be found, requires mandatory statewide control or eradication measures is biologically, ecologically, socially, and economically irresponsible. The proposed law stipulates that these measures be applied to the extent of dictating systems of tillage, cropping, and management and use of livestock on private and public lands--that they be applied even to the extent of destroying growing crops. The proposed law stipulates imposition of taxes, owner-payment of direct costs, and fines for non-compliance. When taken to such extremes, the premise is not only irresponsible but tyrannical."

The foregoing rather strong statements were exerpts from a statement of the Montana Wildlife Federation relative to the proposed 1968 modification of the Montana Weed Control Law. These statements were made by people who were concerned for the wildlife resource in anticipation of a greatly expanded weed control program with many more mandatory provisions, as opposed to the limited and somewhat permissive program which had existed prior to 1968.

*Address to the Weed Control training session sponsored by the Environmental Services Bureau, Montana Dept. of Health and Environmental Sciences, Missoula, Montana, October 12, 1972.

Their fears were based on a long history of watching the quantity and quality of wildlife habitat slowly dwindle away. Herbicides are one of the many modern-day chemicals which can have adverse effects on wildlife habitat.

Before going any further, I would like to preface my following remarks by acknowledging that:

1. The human race has become dependent upon pesticides to maintain its present members and food supply.

2. Control of certain plant species may be necessary or desirable in the commercial production of food and fiber.

3. Wildlife has suffered under intensive agricultural practices involving the use of fertilizers, insecticides and herbicides.

4. Most weed control programs are agriculturally oriented with little or no consideration, or no allowances, made for the diverse needs and circumstances of non-agricultural private lands, city lots, floodplains of streams and rivers, pond and lake shores, and the vast areas of public land, both state and federal, currently managed under a variety of non-commercial, non-agricultural statutory mandates.

We should also look at a few facts regarding herbicides:

1. If properly applied, most herbicides are relatively low in mammalian toxicity. They appear to be somewhat more toxic to fish and aquatic life either because of the active ingredients, its form or the additives in the final products.

2. Some herbicides have been demonstrated to produce teratogenic effects in laboratory mice.

3. To this speaker's knowledge, no attempts at widescale, long-range removal of persistent, pioneering, and dominant plant species have ever been successful. Such plants have the capacity for establishment, regeneration, survival and transport within and between environments. Therefore "eradication" is at best temporary suspension.

4. Herbicides are not specific to "noxious weeds"; they also kill associated grasses, forbs, broad-leafed shrubs, and trees. These grasses, forbs, shrubs, and trees may have tremendous positive value: as food and cover for wild and domestic animals; as sources of organic material for soil building and for erosion control; as sources of temperature control and nutrients for soil organisms; as sources of litter and humus permitting water percolation; and as integral parts of natural plant succession, natural plant complexes, and natural aesthetic qualities of the landscape.

5. In many cases, the people who declare any or all weeds as "noxious" and thereby ordain their control or eradication, are elected officials who seldom are trained in biology or experienced in natural resource management.

6. After at least ten years of field studies we know too little about modes of action, direct and/or indirect as well as sub-lethal effects of herbicides on wildlife species. We now realize that in many cases we are dealing with mixtures of one or more chemical compounds with possible synergistic implications, and more often than not we are limited in what we can find out by our detection technology. Thus, many subtle effects may go unnoticed.

The question of adverse effects are usually related to the viewpoints and emotions of the evaluators. The sellers, applicators and users favor

using pesticides. On the other extreme are the fatalists who abhor the use of any type of pesticide or herbicide for fear of upsetting some "natural" phenomenon. The majority of people lie somewhere in between. Pesticide use philosophies range from "tunnel-vision" objectives to "emergency only" uses.

All judgments regarding pollution or adverse effects are relative and based on the amount of tolerability of the extent of ecological change. Pollution problems involve individual rights. For example, we as individuals really reserve the right to "pollute" our own bodies with nicotine or alcohol--provided we are aware of the consequences. But does the pesticide user have the right to "pollute" outsiders with his private use and personal benefit from a chemical.

In my own opinion, broad spectrum herbicides sprayed on landscape, other than those being intensively managed for cash crops, are potentially--and more often than not--pollutants. The definition of a chemical pollutant in this respect is:

> The introduction of <u>any</u> chemical which has a potential adverse effect on some biological system, whether it be an entire ecosystem or a chemical reaction within an organism.

Admittedly, even table salt has this potential.

It would be virtually impossible for any one person to understand the relationship between the soil, vegetation, wildlife and the chemicals that are applied to the land in an attempt to control its produce. It is enough to become expert in any one of the many facets involved--application (involving drift, droplet size, carrier, etc.), pollution aspects (involving residual

characteristics, toxicity, volatilization, modes of movement in soil and water, physiological effects upon organisms). I am making a modest attempt here to inform you people, who perhaps have expertise in some of the other areas mentioned, regarding possible effects of some of your actions on the wildlife resource.

In searching for some methods, some common denominator, that I could use to express our concern, across the board, and at the same time make it simple, I was left with one conclusion and that was to talk about systems. As most of us know about systems, I feel, therefore, you can relate with our concern and the things we work for. Actually, our whole universe is nothing more than an aggregation of systems. The most vast and basic one is perhaps the planetary system. Everything works and functions because of a balance in the gravitational pulls and so forth. Again, as with all systems, the planetary system is not static, but dynamic with general shifts over time. Astronomers predict that two hundred million years from now the planets will collide, giving insight into how the system is dynamic. This system provides a few of the very basic things wildlife and all of us need. It provides us with light and heat and also provides these in a predictable chronology. Most living organisms on earth have become dependent on light and heat and the chronology of its occurrence. Very few of us would attempt to play with this system. We can understand it in its simple terms and appreciate its need to exist as it perhaps does. As in many other systems, the earth's surface is a dynamic one, changing with the pushes and pulls of the molten mass inside, often producing volcanism, fracturing of rocks, faulting, and other activities that have lifted mountains. Again it is a system that has been pretty well described. It is not static, but slowly changing over time.

The water cycle on earth that all of us were exposed to in school is a system and certainly it contributes to the maintenance of other systems. Stream flow, evaporation, and precipitation are highly variable phenomena. We all are aware of this as we watch the weather. Living organisms on earth are also organized into systems. Community ecology is a study of such systems. These living systems are not static either. The relationships between organisms and their environment do vary with time. Still, at any point, a balance can be described. Much fun is poked at the balance of nature, but all that is really meant by it is that in a given situation, at a given point in time, there are relationships that maintain a balance to the system that can be described and put into perspective. Also factors that are capable of influencing change in the balance of nature can be identified and perhaps predicted.

We now come down from the universe to the earth to living organisms on earth and we must go down even deeper than that in our considerations today. There is one other very essential system. The internal functions that provide life in all living organisms are coordinated. They function as a system of checks and balances and they represent another system, the physiological system. Even below this, one that we know very little about is the system of the cell. All of its balances are inherent in the cells workings. Now, man is a part of these systems and his existence depends upon them. Our basic activities and our basic needs have been provided for and built into this system. Man is a part of nature. However, our technology has enabled us to greatly increase the intensity and scope of our activities. Herein lies our problem. Currently, our activities are greatly disrupting many systems. Not all disruptions are detrimental. Many are not intense enough to create serious, real problems.

The adverse effects that we create are usually the result of an intense disruption of the system. We might use a simile for comparison. We all know what a pocket watch is. Certainly it is a system that has been developed and evolved over time and perfected. We can do a lot of things with a pocket watch. We can carry it with us in an airplane or on a boat. We can twirl it around on a chain. We can leave it out in the open. We do not have to keep it under glass, in other words. But, it is commonly suggested that we can cause irreparable damage to the system if we take the back off the watch and blindly insert a needle in its mechanisms. Too often, the activities of man are done just as blindly. We don't stop, consider, and study what the impact may be. The increasing intensity with which we attempt to manipulate the environment dictates that we carefully assess our actions to prevent such irreparable damage.

So, what are the concerns of wildlife ecologists about our current approach to the use of pesticides to control pests? We really start at a very basic level in our concern. First, we must define some ecological principles. All living organisms have what ecologists call an ecological niche. Now, this is not a piece of habitat, but is a set of environmental factors that provide the life requirements for each kind of organism. Species share many factors such as sun, light and water. As we go down the list, we find that they assume some that are unique only to themselves. No two species depend upon the same set of factors in a given environment. Now, this situation enables full utilization of the habitat and also precludes domination of the habitat by any one group of species. An ecologically diverse habitat provides numerous organisms in the habitat and in the checks and balances and little ability limit the population explosion of the species that are adapted to the habitat. Agriculture, even in its most basic form, tends to develop more simple

habitats. Its purpose is to enhance the ecological niche for a crop and to remove competition. Clean farming removes all environmental factors thought to be detrimental to the crop. Intensified agriculture tends to eliminate all organisms except the crop and the organisms that are uniquely adapted to exist on that crop. Now these later organisms have come to be called pests. Intensive agriculture creates pest problems. It creates them far beyond the level at which they existed under less intense management. This results from the creation of a simple, unstable habitat.

Herbicides affect wildlife because they disrupt plant communities and in some cases may kill or have sub-lethal effects upon organisms.

The purpose of herbicides is, of course, the outright poisoning of the target plant and the intended disruption of the crop pest and/or its seed source. Unfortunately, many of the herbicides we use are non-specific and may kill non-target species on the sprayed area, or drift over to kill nearby non-target plant complexes. All too often, the non-target items represent food or cover species important to wildlife.

Laboratory experiments have shown that some herbicides can either induce or inhibit the production and presence of enzymes and hormones that govern many essential physiological functions in animals. An example was the experiments by the Bionetics Laboratory showing that the chemical 2,4,5-T can cause birth defects in some laboratory animals.

Let's take the pheasant as an example of a species whose environmental niche is closely tied in with agricultural lands. We have seen a drastic decline of the pheasant in the Flathead and Bitterroot Valleys of western Montana in the last 15 years. A good deal of this decline can be attributed

to major, but gradual, land use changes--mainly from production of small grains to grazing livestock, as well as putting into production many acres of swamp and sub-marginal lands which formerly provided cover. On all the lands we have intensified crop production. We have sprayed the undesirable plants or "weeds" which competed with the cash crop and we sprayed the insect pests which threatened to destroy the crop. We sprayed nearby plant complexes to destroy seed sources of undesirable plants and treated ditches and ditch banks for undesirable vegetation so that we could more efficiently irrigate. The insecticides removed the insect life necessary to young pheasant chicks as well as produced residues, which if ingested in sufficient amounts could inhibit reproduction. The herbicides killed vegetation necessary for food and cover as well as plant complexes which provided high densities of insects important to young pheasant chicks. Our current awareness of such impacts of agricultural chemicals on wildlife may represent what could be compared with the tip of an iceberg.

There are also several documented cases of adverse effects of herbicides on trout, pheasants, ducks and song birds in the Post Creek Drainage and Nine-Pine reservoir areas of the Flathead Valley. Rather than enumerate specifics, I would refer you to such publications as "Pollution-Caused Fish Kills" in 1963 (U.S. Dept. of H.E.W. Publ.). It cites an instance (p. 9) where a herbicide was applied to an irrigation canal for weed control. In the past, this was done without any fish kill. This time at water temperature 84° F., it killed 300 largemouth bass, 500 bluegill, 200 bullheads, and 4,000 thread-fin shad. Total estimated kill: 5,000. Other suggested literature might be Pesticides and the Living Landscape by Rudd and the Bionetics Laboratory Report.

That weeds must be controlled in cultivated crops is undisputable. Spreading of the noxious variety should be prevented. We should, however, make sure that the control programs are less damaging than the weeds.

It is common knowledge that nature will fill a void, that effective herbicides will create a void, and that annual plants are the first to appear on undisturbed sites.

Accepting this, it appears that annual spraying will encourage weeds and prevent normal plant succession that would eventually lead to climax vegetation. This would seem to create an exercise in futility.

The defoliating of Viet Nam, the statements and counter-statements by the heads of our federal agencies and the roadside spraying scares has, I am sure, increased public interest in the problems created by unselective application of herbicides.

These and other documented cases of habitat disruption, coupled with the undetermined potential for further adverse effects of herbicides upon animals and habitat, are primarily responsible for the position of wildlife ecologists today against our unselective use of herbicides. Our interests and responsibilities as wildlife ecologists are in maintaining a diverse and healthy wildlife resource. To provide this, we must help provide and maintain the habitat, and the environmental quality of that habitat necessary to support the resource. We do not see the choice as having to be one between wildlife and human necessities. It is rather a question of whether or not land use and resource management can be based on sound ecological principles. We are interested in seeing agriculture become ecologically as well as economically oriented. We believe we can provide for human necessities

and still maintain a rich wildlife resource. However, the herbicide system, the system that we are here today to consider, must be made more flexible and susceptible to change if we are to accomplish this.

I want to thank you for being asked to voice the opinion of the wildlife interest group at this weed control training session.

GROUND APPLICATION OF HERBICIDES

by
M. J. Jackson
Extension Agronomist

Weeds have been a major problem in the production of crops since the beginning of man's agriculture. They reduce crop yields and increase the cost of production. Infestations usually start on land lying idle or on land not properly managed. Disturbed sites usually are the first infested with troublesome weeds.

Weed infestations can be kept to a minimum by applying the know-how we have for control. Of course, the cheapest and most effective method of controlling weeds is prevention. Many of our crop plants can compete with weeds if we apply the management practices that have been proven beneficial. Sowing weed-free seed is absolutely necessary in any weed control program. Proper seedbed preparation, adapted crop varieites, proper crop rotations, adequate fertilization, wise use of chemicals, and applying all practices at the proper time will help reduce weed infestations.

Weed control practices that should be applied by everyone are clipping, cultivation and chemical control. The combination of these practices will give optimum control and prevent new infestations from getting established. The practice of chemical weed control must be thoroughly understood to receive optimum results from the application of herbicides.

Herbicide Application

Herbicides have different selectivities because they have different molecular forms. The variation in molecular forms changes the chemical and physical properties of the molecule, which in turn modifies its biological activity. Among the obvious properties which could influence the selectivity of a herbicide are water solubility, absorption and translocation rates, molecular stability in plants and leachability in soils. Adjuvants and surfactants (surface active

agents) often are included to improve the application properties of a liquid formulation.

Many selective commercial herbicides, for use in specific crops against specific weeds, are available. Herbicides are used either on foliage or in the soil.

Foliage treatment is when the herbicide, usually as a liquid spray, is applied to the leaves of the plant. The plant is affected either by contact or translocation. By contact, only the plant parts actually contacted by the herbicide are killed. However, the non-contacted parts also may die if entirely deprived of the essential parts, such as the leaves. Adequate distribution of the herbicide over the foliage is essential to get optimum control. By translocation the entire plant is killed, because the herbicide moves within the plant. When the herbicide is applied to the leaves, it is translocated to the roots. It also may move from older leaves to young, growing points. It is essential to use a herbicide that will translocate to control perennial plants.

Chemical treatment of the soil is when the herbicide is applied to the surface, or in the soil, by incorporation or injection. The application may be made pre-plant, pre-emergence or post-emergence as related to the growth stage of the crop. Timing of the application, in relation to the growth stage of the weeds and crop, is important. Surface treatment must be incorporated by cultivation or carried into the soil by rainfall, overhead or flood irrigation. If flood irrigation is used, shallow incorporation is necessary first to prevent water from carrying herbicides before penetration.

The response plants (crop and weeds) have to a herbicide treatment depends upon a number of factors. Factors involved are the plant's genetic inheritance, age, growth rate, morphology and physiology, and the biochemical and biophysical processes. Keeping these factors in mind will help growers use herbicides more effectively.

Plant species are different from one another primarily because of the specific genetic make-up of each. Chemical selectivity does not vary too much

within the species, although there are some exceptions. Such response to herbicide selectivity is beneficial because it can be applied in plant breeding programs.

The age of a plant often determines its response to a particular herbicide. Plants in the weedling stage are not as difficult to control as those reaching maturity. Pre-emergence herbicides are used to control weeds before the weed seed germinates. Post-emergence herbicides are used after plants are established, but recommended for application at the one- or two-leaf stage.

The growth rate of plants has a pronounced effect on their reaction to some herbicides. Plants that grow rapidly generally are more susceptible to herbicides than the slower-growing ones. The plant processes, such as absorption, translocation and metabolism, proceed at a much faster rate in the rapidly growing plant.

The morphological differences in a plant are in the root system, location of growing point and leaf properties. The make-up of the root system will vary as to whether the plant is an annual, biennial or perennial. An annual plant has a shallow, fibrous root system. A biennial has a deep, tap-root, and a perennial has deep, rhizomatous-type roots spreading horizontally for many feet.

An annual weed can be easily controlled by herbicides because only the top growth has to be killed. Perennials are more difficult to kill because the chemical has to be translocated deep into the spreading root system. If the root system is not affected by a herbicide, regrowth will occur. The control of annual weeds in a perennial crop is successful because of the difference in their root systems.

The location of the growing point of a plant determines the effect herbicides have on it. Plants that have growing points located at the base (cereal grains) are protected from contact herbicides. With the growing point below the soil surface in some cases, and the leaves protecting it, grass plants are quite tolerant to many herbicides. Broadleaf plants have exposed growing points at the tips of the shoots and in leaf axils, and are quite susceptible to chemical injury.

The response received from the application of herbicides on plants also is determined by their leaf properties. Plants that have narrow, upright leaves, waxy surfaces, or leaves which are corrugated (small ridges), are protected from chemical sprays. Water droplets do not adhere to this type of leaf as to those found on grasses or grass-type plants. Broadleaf plants having wide, smooth leaf surfaces hold more of the chemical spray, thus having a greater effect on it.

The physiological differences in a plant determine how much herbicide is taken up by the plant (absorption) and the extent it moves within the plant (translocation). The absorption and translocation of a herbicide varies between different species. The greater amount of herbicide absorbed and translocated by the plant, the greater degree of kill.

Plants that have thin cuticle (waxy layer) or large stomata (pore openings) on leaf surface absorb more herbicide chemical. Adding wetting agents to herbicide formulations increases the killing properties by increasing absorption of the herbicide. The full effect of a herbicide is not received by good absorption alone. Once a herbicide has entered a plant, it must move to other parts to give control. The movement (translocation) of the herbicide within the plant occurs both upward from the root to plant parts above the soil, and downward from the leaves to the roots. Translocation rate and the amount of herbicide translocated vary with different herbicides, and among plant species. It will vary also within a species under different environmental conditions.

Biophysical-biochemical herbicide selectivity in plants involves five factors: adsorption, toxicity, enzyme reaction, activation and decomposition.

Adsorption - Adsorption of a herbicide by plant cells can inactivate the chemical and limit herbicidal action. This is caused by the surrounding plant tissue slowing down the movement of the herbicide. It also can be tightly bound to some plant constituents and not readily translocated.

Toxicity - Toxicity of oils to plant tissue is determined by the flow of the oil within the plant cells. When the oil damages the cellular membranes and allows the cell sap to flow into the intercellular spaces, the cells die and cause the plant to dry out.

Enzyme activity - Many herbicides reduce enzyme activity in one plant species and not in others. This activity can cause some plants to die and leave others unharmed.

Activation - Herbicide activation also can cause some plants to die, and leave others unharmed. The application of 2,4-DB on alfalfa will leave the alfalfa (legume) unharmed, but other plants can change the 2,4-DB to the weed-killer 2,4-D. Herbicide inactivation occurs when some plants cause the herbicide to decompose into a harmless compound. An example of this herbicide activity is the decomposition of simazine applied to corn.

Environment - The dominant factors of environment which affect selectivity of herbicides are soil type, rainfall or overhead irrigation and temperature. The type of soil and the amount of rainfall will determine the location of the herbicide in the soil, and the temperature will determine the plant activity. Moisture and temperature affects the herbicidal activity within the plant.

Placing a herbicide in varying depths in the soil can make it selective in controlling certain plants. High-water soluble herbicides can be leached into light soils with high rainfall to control weeds with deep penetrating roots Low-soluble herbicides applied to heavy-type soils with limited rainfall will control shallow-rooted plants. To vary the depth of the herbicide in soils is helpful in controlling deep-rooted weeds in shallow-rooted crops, and shallow-rooted weeds in deep-rooted crops.

AERIAL APPLICATION

R. B. Allison

It is not my purpose to stand here and give you flying lessons. We all know this is not possible, but maybe I can offer some tips that may be helpful.

To begin, let me say the airplane application industry has come of age and my first suggestion is that you drop the words "crop duster" not only from your advertising but from your vocabulary. To much of the public, these words conjure up the image of a daredevil pilot with leather helmet, goggles and white scarf, skimming the ground in an open cockpit bi-plane.

When I first started in this business 28 years ago in the Yakima Valley in Washington, the spectacle of an airplane dusting a field of potatoes or peas was enough to stop traffic a mile in each direction, so it was only natural for the pilot to put on a show for his audience.

Today if someone stops to observe my work, I know it is either the farmer on whose field I am working, one of my competitors, a tourist, or someone from EPA.

Further evidence that our industry has come of age and outgrown the tennis shoe Air Force image is evidenced by the NAAA--National Agricultural Aviation Association, formerly the National Aerial Applicators Association. The name was changed because secretaries in Washington, D. C. thought we had something to do with the radio and TV, so there is something in a name.

In 1967, two hundred people sort of sneaked into the Marimont Motel in Dallas for the first convention of the newly formed NAAA. Last year we went back to Dallas 1,000 strong to the Craigmont--the ritziest hotel in town, at their invitation. This year we expect 1,400 at our convention in Las Vegas.

You may wonder what all this has to do with the aerial application of herbicides. Well, gentlemen, with the present trend toward environmental protection at any cost, an emotional public, an unfriendly communication media, a government agency with the power of life or death over your business whose decisions are sometimes

based on public pressure and political expediency rather than scientific fact as witnessed by the banning of DDT, you need a strong voice in Washington to give yourself a chance to apply herbicides correctly.

The key person on any aerial application is, of course, the pilot. You may have the best and most modern piece of equipment and the correct material mixed just right and sufficient for the job, but if the application is sloppy, the result is a poor job. By the same token, the best pilot in the world can't do a good job with leaky equipment, plugged nozzles, etc., so the two sides of the coin must be correlated. This is the job of the owner or manager.

You have probably read scientific treatises in application that mention height above the drop in terms of one wingspan or two wingspans. It may be true that this is the elevation that will give the maximum swath width but it also gives the greatest chance for evaporation and drift. I fly a Snow and if I were to make my applications 45 ft. above the crop, I wouldn't get much repeat business. However, the old idea of low and slow and drag your wheels in the crop is just as wrong. The altitude you fly must be a compromise between maximum swath width, effective penetration, and minimum evaporation. Swath width will vary according to height of release, kind and arrangement of spray equipment on the plane, wind velocity, and wind direction in relation to the spray run. Always remember that flying into the wind narrows the swath.

It is necessary to calibrate the airplane at the altitude and speed at which the real job will be done. It doesn't do any good to calibrate at 80 m.p.h. if the job is flown at 100 m.p.h. There is no device presently available which will automatically flow as the speed of flight changes, so keep the speed the same.

I would also suggest that you check the pattern. This is especially necessary if you are applying residual herbicides which must get to the root zone to control weeds. If your application is too light, you don't get all the weeds; if it is too heavy, you are wasting your customer's money. Pattern may be checked by laying out a strip of butcher paper or adding machine tape and using food coloring in the spray.

One of the most important gauges of your airplane should be a thermometer. It can be an outside temperature gauge on the dash or an old barnyard type taped to the strut. Whatever the type, use it to check for an inversion on the way to the field. This is the most dangerous time for herbicide applications. Dr. Yates of the University of California at Davis gives this comparison. If with a ground rig I must stay 500 feet from a susceptible crop with a 7 m.p.h. wind and normal lapse rate, with an inversion and a 3 m.p.h. wind, I must stay 1,500 feet away. Let me repeat--500 feet with 7 m.p.h. wind normal, 1,500 feet 3 m.p.h. wind during inversion.

For those of you who use the automatic flatman, I have found it helpful in rough terrain to circle fly a field.

One word of caution before I close, never fly directly over houses. If at all possible, avoid doing so. You are lucky to be operating in areas where there are no grapes and very little urban sprawl. People who are not agriculturally oriented and who move to the country for peace and quiet can become very irate when awakened at daybreak by an airplane which sounds as though it were going to take their roof off. A little public relations work and pre-flight notification can save a lot of headaches and possible law suits.

Herbicides and Mimics: Effects on Non-target Plants.

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While the effects of drifting or leaching herbicides on non-target plants are fairly well documented, the effects from other chemicals and environmental stresses which mimic chemical herbicides are not too well recognized. In the winter of 1972-73 Montana experienced an open January with temperatures in the -30°F range and constant dry easterly winds. This was followed by a spring into mid summer series of frosts or near frosts. Temperatures ranged from around 35°F at nite to 95-100° during the day. These temperature fluctuations placed a severe stress on all plants, from trees to grain crops. The first symptoms observed in early spring were formative effects to leaves, petioles and leaf spots not too unlike 2,4-D or 2,4,5-T effects. Later these leaves died and with subsequent investigation it was concluded that these symptoms were caused by temperature stress.

A number of active plant pathogens cause herbicide-like symptoms. There are a number of viruses which will produce leaf clearing, bonding and strapping, excellent mimics of herbicide injury. We have recently discovered that alfalfa white top, long thought to be cold injury and looking very much like amitrole damage, ie. actually the effects of the stem and bulb nematode.

Air pollution damage strongly mimics herbicide effects. Hydrogen flouride coming from smelters can defoliate and eventually kill most trees. Lilacs and gladiolas are particularly susceptible to HF fumes. Ozone, PAN (Paraacetyl nitrate) and a number of other industrial and auto waste materials damage plants.

The persistance and movement of certain herbicides can present many problems, especially in urban situations. Picloram, dicamba, simazine and other soil sterilants must be used with utmost caution and thought about future use of the areas on which used. These are long lasting and/or leachable materials that can either render the soil treated sterile for great periods of time, can leach in the soil solution, or may move on the surface with soil particles moved by wind or flooding. Misused these chemicals may cause an applicator or home owner lawsuits due to non-target damage to neighbors plants.

Volatility and drift of ground or aerial herbicides present unique problems on non-target plant damage. A fair knowledge of the physics of volatility and drift, plus meteorlogic phenomena must be had to understand and estimate the potential for damage under the many varying conditions encountered in open air applications.

Non-target herbicide damage to plants is the result of error, but these errors can be minimized through education. In order to save what precious few uses we have left, the applicator must recognize the pitfalls of herbicide usage and also be able to recognize those damages mimicing herbicide action. Don't guess at the problems cause, consult an expert.

SAFETY IN HANDLING AND STORING PESTICIDES

James J. Boland

In any given year a number of people become ill or die as a result or overexposure to pesticides. The circumstances of exposure may include, among others, the child who finds a pesticide improperly stored or carelessly placed in use and eats or drinks it, or a workman in a formulating plant or farmer in the field who accidentally spills a pesticide on himself but does not take the necessary action to decontaminate himself and seek medical aid. Regardless of circumstance, most of the illnesses and many of the deaths associated with pesticides could have been avoided.

Although our attention this morning will focus on safety precautions for the worker and applicator of pesticides, perhaps a word should be said about the occasional user of pesticides, the homeowner or weekend gardener. Although not desirable nor totally justifiable, the availability to the homeowner of concentrates of pesticide materials, some in the area of eighty percent technical material concentration is easily documented by a casual perusal of existing pesticide stock in some retail outlets.

In this instance, the product label is the best source of information. The product label is an excellent source of information. Utilization of this information is synonymous with reading the label. The information contained on the label represents an investment on the part of the manufacturer of 4 to 6 million dollars.

The label gives such information as active ingredient(s), mixing and application rates, target organisms, indication of toxicity, warnings and specific treatment in case of poisoning.

Frequently illness follows when the label is not read. State Services Branch workers[1] have shown that sources of product information are frequently friends, merchants, etc., the information being passed by word of mouth. This circumstance will tend to predispose the user not to read the label or the product may be transferred from friend to friend via the "Coke" bottle route, often with tragic consequences.

In considering safety concepts in the manufacture, formulation and application of pesticides, our approach should be to minimize worker hazard and preserve the integrity of the environment. It is under the conditions of manufacture and formulation that the danger of exposure is greatest, for these conditions usually involve the handling of concentrated materials.

How may we insure worker safety under these conditions? Perhaps we want to consider two approches -- one direct, the other indirect. The indirect approach may include, but is not limited to, the following:

(1) Education - We will presuppose that the manufacturer or formulator is knowledgeable concerning safe handling procedures. (This is something which you may have to determine to your satisfaction.) A worker who understands the dangers of the product(s) with which he works will readily recognize the importance and necessity of the precautions he is to take. He can do much to insure his own safety. Toxicity, routes of absorption, signs and symptoms and instruction to seek medical aid if he has or thinks he has had an exposure, are points to be incorporated into his educational program.

(2) Personal hygiene -- When not advised to do otherwise, the worker will frequently wear the same work clothes day after day. When working with pesticides clothing frequently becomes contaminated. In this case daily contact with even low tox materials could result in illness. By stressing such factors as washing prior to eating/smoking, daily shower and clothes change, much can be done to insure worker safety.

(3) Medical supervision -- Periodic testing of blood cholinesterase activity and/or metabolite excretion will generally serve to detect trouble in a worker who is experiencing an undue exposure and is in danger of perhaps developing a toxic illness.

Protective devices and clothing which physically prevent exposure to pesticide materials are classified, for the purpose of this discussion, as direct methods designed to minimize hazards associated with pesticide processes.

Routes of entry -- dermal, oral and respiratory -- are all important to the worker. The dermal route of exposure is the most significant to persons involved in the manufacture, formulation or application of pesticides. Wolfe[2] and his coworkers in Washington State have shown in a study of several hundred pesticide applicators that over 97 percent of the pesticide to which the body was subjected was deposited on the skin. This was especially true of applicators applying liquid sprays. The importance of protecting the body surface from contamination is obvious.

Factors such as fatigue, carelessness, boredom with the routine of many plant operations and the sheer bulk of many of the pesticide product elements would be important considerations when we consider the causes of some spills. Gross contamination of workers and their environment is the end result, with concomitant health hazards.

Work by Maibach and Feldman[3] in California showed that pesticides are more readily absorbed from some body areas than others. Using C 14 labelled parathion as a representative compound, these investigators found the range of absorption to be from 9 percent forearm to 100 percent in the scrotal area. Saturation of clothing with parathion or like substances that are readily absorbed across the intact skin through spillage or saturation by sprays would be akin to an injection of the material directly into the vein.

The importance of this last observation takes on added importance when we think for a moment about the the tendency to carry objects or packages which are heavy or unwieldy in the so-called "gut" carry position.

While cloth provides some degree of protection, waterproof trousers are recommended. A waterproof apron would be second choice. Daily changes to clean clothing and daily shower are both important adjuncts to direct protection of the lower body.

Absorption is somewhat less efficient over the upper body; this area still has a significant exposure potential because of the large body surface. A waterproof jacket or raincoat with long sleeves and a close-fitting neck should be used. This gives protection to the upper back, shoulders and forearms of the worker.

The principal objection to the types of protective gear we are speaking about is that in hot weather it becomes very uncomfortable. Worker comfort is in fact an important consideration. Worker discomfort will frequently result in our "well protected man" being seen by mid-morning wearing a T-shirt and baseball cap. What should be encouraged under extreme heat conditions is at least insuring minimal protection by use of a long-sleeve, GI-type cotton twill shirt which should be laundered after each use and changed when it becomes wet with spray. This should never be considered adequate protection, but merely a compromise between nothing and at least minimal protection.

Protective clothing of the lighter colors can be as much as 8-10°F cooler than the familiar black or dark green type.

In the head and neck area, Maibach et al. found absorption of parathion to be 32-47 percent of the applied dose.[3]

Headgear with a bill or brim will give some protection to the scalp, face and neck area. A waterproof hat with a wide brim is available that affords good protection to this area of the body.

Goggles and respirators provide considerable protection to the face area but should be properly cleaned, serviced and stored.

The high potential exposure to the hands emphasizes the need for wearing gloves. Cloth-type gloves are not recommended as they can become soaked with pesticides and then enhance--not prevent--exposure. Rubber gauntlet-type gloves can be turned out for easy cleaning.

Waterproof shoes or boots provide the best protection for the feet. The trouser leg should be worn outside the boot or shoe top to prevent runoff from going into the boot. Leather work boots become dried and crack when repeatedly soaked with pesticide liquids; this makes them unacceptable as protective gear when handling toxic materials such as pesticides.

Adequate respiratory protection for most types of application is provided by the use of cartridge-type respirators. In some instances, such as manufacture or formulation of extremely toxic products, self-contained or supplied-air type breathing apparatus is used. The oral route of exposure probably is not one of major concern in occupational exposure. It is usually difficult to make a clear distinction between oral exposure and respiratory exposure. Few workers would intentionally eat these products with which they work. Pesticide residues may be on the hands and transferred to lunch or snack items. Therefore, washing before eating and smoking is the best prevention for this type of exposure.

Let us now consider the safe handling of pesticides in other important areas--transportation and storage.

Pesticides may be shipped as the technical material--usually this is the undiluted chemical of up to 95% pure material--or as formulations which are mixtures in which the technical material is combined with a carrier or solvent permitting conventional application.

Hazards to workers in the event of a spill in transit, occur through the same mechanisms as those considered earlier. This is, they may be absorbed, inhaled or ingested. This may occur through contamination of items which are co-shipped or during the cleanup process. Ingestion may occur if contaminated foodstuffs are allowed to reach consumers. Pesticides cannot be shipped with foodstuffs unless they are packaged in air-tight wrappings. Unfortunately this regulation is sometimes ignored or wrappings break and the danger of secondary poisoning still exists.

Cleanup involving pesticides should be performed only by authorized persons. These persons should use adequate measures to protect themselves in the situation including measures discussed above.

The National Agricultural Chemicals Association has formed a network of safety teams to minimize the risk of injury from the accidental spillage or leakage of pesticides.

This network became operation in March of 1970. By contacting a central telephone number (513 961-4300), the team network insures that expert help will be dispatched to the scene of an accident. The safety team network furnishes personnel, equipment and expertise, to insure prompt, efficient cleanup and decontamination following major accidents involving pesticides.

Another form of assistance in general chemical emergencies is the establishment and function of the Chemical Transportation Emergency Center (CHEMTREC), established by the Manufacturing Chemists Association (MCA).

The CHEMTREC number is 800 424-9300; in Washington, D.C. the number is 202 483-7616.

The Department of Transportation, Office of Hazardous Materials is assisting in the dissemination of information concerning the newly established central information point for Chemical Transportation Information (CHEMTREC).

The Chemical Transportation Emergency Center (CHEMTREC) provides emergency personnel with information on safety measures in handling hazardous chemicals involved in accidents on the nation's highways, railroads and waterways. A voluntary program of the Association, which has 165 U.S. member companies, CHEMTREC operates on a 24-hour basis, seven days a week with a nationwide telephone number.

CHEMTREC is not a source of general chemical industry information, such as how to locate a missing shipment; nor is it a policing agency. It is a source of assistance to official organizations concerned in chemical transportation emergencies and is designed to provide immediate data on how to handle these emergencies to those who are trained to do so. The Manufacturing Chemists Association initiates this new program to protect emergency crews and the public has been in development for the past 15 months.

Further information may be obtained by writing either the MCA or the Department of Transportation, Washington, D.C.

The danger of fire in warehousing pesticides is a major public health hazard. Fires involving pesticides are especially hazardous because of the possibility of poisoning from vaporized chemicals added to the usual fire hazards of smoke inhalation and thermal burns. Containers of pesticides rupture. Water and chemicals used to fight the fire spread contaminants over a wide area. Heat and air currents combine to vaporize pesticides and cause them to enter the air. Fire fighters must take extraordinary precautions to avoid breathing fumes and smoke from ignited storage areas and avoid body contact with water and debris.

To summarize, the overriding theme put forth in the preceding pages has hopefully been one of common sense practice when dealing with pesticides or other hazardous chemicals. By using either the direct or indirect approaches to safety, or a combination of the two, we can expect to substantially reduce or eliminate the risks incurred when using toxic chemicals such as pesticides.

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SELECTION OF A HERBICIDE

Vern R. Stewart

It is really exciting to become more informed about what is going on about us, what our neighbor is doing. Sometimes I wonder if we would be quite so critical of the things that are happening in our environment if we really knew the facts. What is the benefit of a particular function or operation to the environment? Well, better get back to the point of research instead of getting out here on the limb on philosophy. A funny thing about philosophy, you don't have to have too many facts.

Dr. Larry Mitch at North Dakota State University reported that if 2,4-D were banned, North Dakota and Minnesota wheat producers would be put out of business. The control of weeds in a wheat crop with 2,4-D means there will be a profit--without weed control, no profit.

Workers at the University of Wyoming found that one pigweed growing beside a sugar beet plant--this is one beside each sugar beet plant throughout an acre--would reduce the yield about 60 to 70%. Just one little weed does that.

SLIDE 1: I have a few slides I would like to show you, just to illustrate some of the work that we have done at the Northwestern Agricultural Research Center which aids us greatly in selecting a herbicide. One of the bases of selection of a herbicide is the research conducted. I want to discuss some of our research data and then consider some specific points in selecting a herbicide.

The study I will be discussing was one done on field gromwell. We had a tremendous problem with this particular weed species. We made an all out effort to remove it from small grains. It was evident from observation without any yield data that this plant was really robbing the wheat of moisture and nutrients Therefore, we felt that we had to do something about it. Before we could select a herbicide we had to do some studying. This also helps bring out some of the points of why use a herbicide. The value to the environment and the value to people, which is really our end product in this world.

This study was designed to find out: (1) What was the effect of weeds on the crop? (2) How can we most effectively control them? (3) What product or herbicide would be the most effective? In all research work you always have to have a check. The first slide shows a plot where we mechanically removed all of the weeds in the fall. The study also contained chemical treatments applied in the fall and spring and non-weeded checks, also plots hand weeded in the spring, about the approximate time one would apply the old standard 2,4-D for weed control.

SLIDE II: Shows the effect of the bromoxynil, the herbicide we finally found to be the most effective on field gromwell in this study. You will note the tremendous weed population on the right as compared to the almost no weeds found on the left. This is a real late fall picture. The herbicide was applied the last of October. We obtained excellent weed control with this product. Bromoxynil is not a hormone type, but a contact herbicide; by this I mean the weed or plant has to be present before the herbicide will have any effect. This is in contrast to 2,4-D which everyone is familiar with, which is a hormone type herbicide. This type herbicide is translocated through the plant, goes into the root and kills the plant. Whereas the contact herbicide, in this particular case, bromoxynil, applied to the leaves and interferes with photosynthesis and the normal function of the plant and the plant then is killed. I find this picture fascinating. We can do such a beautiful job in removing the weeds. There is real competition with the wheat plant at this stage of growth. Both are using nutrients and moisture at about the same rate. By removing them in the fall you really give this little wheat plant a boost. My following slides will illustrate this more graphically.

If we hadn't removed those weeds early in the fall we would have the situation you see here. On the left you see the tall weeds. Weed seeds are seen in the plot on the left as contrasted to the plot on the right, which is weed free.

In this particular case it is the hand weeded check as contrasted to the non-weeded check. So you can see in a season's time the plant really moves in there and really takes out the wheat. Notice the difference in the number of heads per foot. Do you see that in that picture? It is real graphic. Again it points out the need to use herbicides.

If one is going to use herbicides, well then he wants to use them wisely and effectively. This is a picture taken in Washington. The check is on the left, but on the right we have many, many gromwell plants showing. This was sprayed, but application was too late. This is an illustration where it wasn't applied at the proper time. It is a loss of money to the operator in this particular case. This is another illustration of the improper timing of the herbicide. They just didn't get it on early enough; in this particular case the field gromwell was too large. This is another thing in selecting a herbicide--when do you apply it?

To me, this is one of the most graphic illustrations of any work I have done in the field of weed control in farm crops. The one on the left was hand weeded in the spring, May 10th or 12th, about the time when winter wheat would be large enough to apply 2,4-D to control the weeds, the usual practice. On the right is the plot that was hand weeded in the fall as I showed you in the beginning. Look at the density of the heads and also look at the height of it. The yield data from the weedy check, the spring weeded and the fall weeded were as follows: 29 bu/a for the weedy check, 46 bu/a for the spring weeded and 62 bu/a for the fall weeded. So, this is a really graphic illustration of what fall weeding can do. Of course, we all realize that hand weeding or mechanically weeding in the fall is just about impossible in our present cultural systems, but with the use of agricultural chemicals as shown in previous slides, we can do a pretty effective job in controlling these weeds. We found that if you don't control these weeds you just don't get anything. Recently I was talking

to a farmer who said that he fall sprayed his winter wheat and did a tremendous job in controlling the weeds. He missed a few spots while he was spraying and in those spots he had no wheat. They really robbed the plants of water and nutrients. Of course, in the Flathead Valley they speak of field gromwell as "weed thief" and I don't know who named it, but it is a very good name; it really "robs" the wheat.

Well, let's go back; let's consider the factors in the selection of a herbicide. I think the first factor to consider--what is the weed problem? Probably the best way to consider a weed problem is to get out and look at it. I often wonder as I drive around the fields, this is the fastest way, but is it the best way? What one really needs to do is to get out and walk across the field, actually see what the weed problem is. I think this is particularly true of the winter wheat. Winter wheat comes up, it looks nice in the fall. If the field turns green, we think it is really great, but what we really should do is ask ourselves, why is the field turning green? Walk across these fields and make an evaluation of the weed population, keeping in mind all of the time, yes, they are small today, but they are tremendously competitive as I mentioned. The weed problem today is going to get worse tomorrow and by spring, as I illustrated, could destroy all or a high percentage of your crop. What is the weed problem? What are the species present? This determination has to be made. Then the next determination is what crop is to be grown or what crop is growing in the fields where your problem exists. Then you might still have to ask yourself still another question--what is your cropping sequence, or what is your rotation? Can you use a particular chemical or herbicide, or what technique do you use to control the weeds because of the cropping sequence. We could spend considerable time on this because cropping sequence depends upon the type of weed problem you might have. I think we can best illustrate this with

a rotation we have at the research center. Where we have very effectively controlled the weeds we use a five year rotation. Three years of legumes, potatoes and grain. We found that we have little weed problems if we use clover or alfalfa, but if we put sainfoin in the rotation, then we have a tremendous weed problem. We have to use a different technique to control.

Let's say you have established your problem. Now you need to know what herbicides are available. Gentlemen, this is really critical as far as I am concerned. All of these products are labeled. They are labeled by Federal law and one just has to sit down and take time to go through the label. You have often heard said, "When all else fails, read the label." I am sure that most of you are very aware of this, but it doesn't hurt to point this up again and again; read the label, know what is on that label, know what the product should be used for. If you have determined your problem, know the crop to be grown, then start reading labels to see what herbicide will resolve your problem. Ask for help from the experiment station, extension service, weed distributing company representatives.

When considering a herbicide, consider the effect it will have on the crop. Or you might ask--what effect will it have on succeeding crops? Probably the best illustration of this is some of the Triazenis, such as atrazine, which is used on corn--can you follow a grain crop? The answer is NO.

I think another factor that's important in selecting a herbicide is: what is the margin for crop safety? Some of these products are getting down to a pretty fine point. You have got to be pretty accurate with your equipment measurements to make sure you don't cause any crop injury. The best illustration of that is when we attempted to use picloram in small grains. It could be used, but the margin of safety was very small. You didn't have any room for errors. With 2,4-D, you do have some room for error. You can't kill the crop completely, but you can really

hurt it, but isn't one that will just wipe it out. This is also true of bromoxynil; you can use ½ lb. of that and maybe even up to 1 lb., mistakes and not hurt your crop too badly. Of course, then I already mentioned the fact, does this product have a label for the crop you are concerned with? Can you legally use it on a particular crop? Of course, this is part of our work at the research center. We can check these out and see what effect they have on a crop. We do biological assay on the soils. We can obtain chemical analysis from either the company or by other laboratories. The EPA has to evaluate all these products before they are released to the American consumer. There is quite a routine that these products have to go through before they are even ready for the American consumer.

Read the label, what does it do? What does it say it will do? Where can you use it? How legal is it? So, when you go out to select a herbicide, there are various points you should consider and consider carefully and never forget the economics of using them. We don't have the time to talk about the use of specific crops. If there is time for questions I will try to answer them. If I can't, I hope I can find someone who has the answer here or will send it to you at a later date.

SELECTION OF A HERBICIDE

by
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Introduction

Here are a few questions you should answer before selecting a herbicide. What is the weed species you want to control, not eradicate? You should not consider eradication except on a specific plant in very small areas. Even then it is difficult. What is the specific crop, small grains, tame pasture, hay or range, including forested areas, that is to be treated? What animals are going to be in the area? Most of the time, the only animals that are taken into account are domestic livestock. What affect will the treatments have on wild animals in the area? Quite often this aspect is neglected. What is the best time for treating for the specific species that you are trying to control? Should it be applied in the spring, summer, fall or winter? What affects will the soil type and physical condition of the soil have on the effectiveness of the specific material that you plan to use? What type of application should be used? What are the weather conditions before and likely to be at the time of application or the day after? What are the non-target species of plants in the area to be treated? How important are they to the area? Is the plant you are trying to control a broadleaf in a broadleaf, is it in a grass or is it a grass in a grass, or in a broadleaf crop? Is the growth habit of the plant you are trying to control an annual, biennual, perennial, or woody? It is important that you know what the effects of the herbicides will be on the plants that are being controlled.

Specific Weed Problems

It is important that you know what affects the herbicides will have on the plants that are being controlled. In some situations the plant to be controlled contains toxic materials to livestock and when sprayed with a herbicide toxin levels can increase. This is the importance of knowing the plant species you are going to control and the effects of the herbicide on the plant when possible.

There are severaly types of annuals. Spring annuals are the ones that account for most of the weeds in small grain fields. There is also winter annuals, such as cheatgrass and field gromwell. A winter annual is one that germinates in the fall, then over winter as a seedling and produces seed in the spring or early summer.

Spring annual weeds in an annual crop is not generally a major problem if the crop is a grass and the weed problem a broadleaf. The problem begins when we have an annual grass problem in an annual grass type crop, such as wild oats in grain. There is a choice of herbicides to control wild oats. The choice is whether to use a pre-plant incorporate material or a post-emergence material. The time of application is very critical with the post-emergence material. A good job of incorporation should be done with good moisture present to get good activity with Fargo. On land that is too rocky or too rough, good incorporation may be impossible. At the present time, there is research being done to find a new compound for better control of wild oats with fewer problems than we have with the present products.

There is an existing problem with winter annuals in winter wheat. An example is field gromwell, a broadleaf weed, and cheatgrass. Field gromwell should be treated in the fall or very early spring for best results. Good cheatgrass control with a herbicide in winter wheat has yet to be accomplished. There is considerable research being done to find a herbicide for post-emergence control of cheatgrass. Other grass problems is with cheatgrass in a perennial grass. With this situation there are only a few compounds to select from for specific situations. When the problem is with a grass within a broadleaf crop, such as pure stands of forages, then there are differe approaches to the problem. You can use a chemical, soil applied with a short or long soil life, or cultivate to take care of the grass. For soil applied materials on dryland, the fall is the best time to apply because thay require moisture for activation. Applying the herbicide in the fall gives the chemicals time to be carried into the soi and become active before spring growth begins. Grass problems in tree rows or shelter

belts on dryland can be controlled with the proper chemical and rate. By using the proper compounds at the recommedned rates, the tree rows will also be kept clean of broadleaf weeds, except for perennials, that were already established at the time of treatment.

Biennuals are plants that produce a rosette type of growth the first year and produce seed the second. The control of a biennual should be done the first year when plants are small. Control the second year after the plant has started to bolt becomes very difficult because of resistance to chemical action. Perennials are easiest to control the first year when they have the growth habit of an annual. Generally, perennials are very difficult to control beginning the second year and thereafter. Very few people know what perennials look like the first year of growth. Quite often perennial seedlings are hard to find unless some mature plants are present. Spraying of perennials should be continued each year to keep under control seedlings that germinate after the established plants are removed. Once spraying has started on a perennial you are committed for at least 10 or more years.

Non-target species should be considered in any spray operation and quite often are neglected. These non-target species include brouse and some types of brush for livestock and wildlife. Sometimes non-target species can be avoided if spot treatment is used in place of broadcast.

The control of broadleaf weeds within a grass, whether an annual or perennial, is usually not a great problem if persistance in spraying is used. Broadleaf weeds within a broadleaf crop presents some problems. It depends on whether the crop is an annual or perennial. There are materials of different types that can be used to control broadleaf annuals in a broadleaf perennial crop. It is a problem developing compounds for use in broadleaf perennial crops to control a broadleaf perennial weed. Some work is being done injecting high rates of herbicides in the soil, on crop land, for control of deep rooted perennials.

Types of Herbicides

Herbicides work in a variety of ways. Systemics can be applied to either the plant or soil. Plant applied systemics include familiar chemicals, such as 2,4-D, and MCPA. There are different modes of action of the systemic including hormones, inhibitors and cell destruction. Hormone types cause the plant to grow to death. Inhibitors are of the type that block essential functions within the plant such as prevention of chlorophyl formation, conversion of food to energy, or production of food. Cell destructing types destroy all cells that it comes in contact with. The material is usually translocated by water and minerals throughout the plant.

Soil applied materials are translocated similarly to plant applied materials. When using a soil applied material there must be good soil moisture or anticipation of good moisture. These chemicals must be applied to the soil surface to become effective. This means the ground must be bare when using liquids and if trash is present granuals may be used. Is the herbicide to be incorporated? If so, how deep and how soon? Incorporation or mixing is very important to some materials and a good job should be done. Poor incorporation usually means poor results. Some materials must be kept in the surface few inches of soil and left undisturbed for good results. Most of the materials used around trees are of the soil sterilant type. The material must be retained in the surface few inches of soil and by using the right chemicals and rates good control of weeds in trees can be obtained. If chemical retention near the surface is desired, the solubility of the herbicide to be used becomes very important. If very little moisture or precipitation will be available, such is the case on most dryland, then the higher soluble herbicides should be considered. Another type of selectivity besides placement in the soil is biological. This simply means that the plant is resistant to the specific herbicide.

A question that arises quite often is, should I sterilize the soil to get rid of a perennial weed? No. Your best friend and helper is plant competition. Also, when

you sterilize the soil, plant cover is removed and the area is subject to erosion. Quite often the first plant to reappear is the one that is being controlled. Exceptions to this is around buildings and areas treated for fire control and neatness.

Type of soil is important when using soil applied materials and depends upon whether the soil texture is light (sandy), medium (loam), or heavy (clay) as to the rate of chemical to apply. Soil applied materials should not be used on light soils. Medium to light soils require considerable care as to chemical rates because the material can leach to the deeper roots of a plant and cause injury. In heavy textured soils, higher rates are often necessary to compensate for soil tie-up of the chemical which makes less of the material available to the plants. The level of soil organic matter can also affect the rate and effectiveness of a herbicide. High organic matter requires higher rates of material while low organic matter lower rates. Most of Montana soils are in the medium range of organic matter.

Contact chemicals fall into two categories, non-selective and selective types. Non-selective materials will kill all green plant tissue that is present. In the case of perennials, which have food reserves in the roots, regrowth will usually appear while annuals will usually be completely killed. There are a number of contact selective type materials available. Bromoxynil is an example of a broadleaf contact killer. The selective types are not generally broad spectrum killers. These are, however, being used in crops with good results. One important consideration with all contact chemicals is that they are generally low in volatility and it is a must to get good coverage on the plants for good results. Quite often this calls for an increase in the volume of the carrier and the addition of a wetting agent. Wetting agents can sometimes help but they can also hinder. Read the label on the chemical container before using a wetting agent. You may have to check with the company or a qualified person to determine when to use a wetting agent. When using a wetting agent be sure it is the right one. There are three types; non-ionic, positive and negative.

Most wetting agents are of the non-ionic types which have no or very low affinitive to any other compound.

Combinations of Herbicides

When selecting a herbicide, select one with the lowest volatility to do the job. Amine formulations are lower in volatility than esters. One area of consideration is that of mixing herbicides for better results. Before mixing herbicides, be sure to read the label or check with the Company or some qualified person to determine if the combination is compatable. Also check to see if the combination isn't already commercailly available. Avoid mixing amines and ester formulations because they are not always compatable.

Weather and it's Importance.

Weather is one of the most important factors affecting the use of a herbicide and is quite often the least considered. Weather conditions before application is more important for soil active materials than plant applied materials. What is the weather conditions going to be after application? This question generally is left unanswered and no attempt is made to consider it other than if I don't do it today will I be able to do it tomorrow? When possible, try to time the application to the weather best suited to the activity of that specific material. Weather plays an important part in the decomposition of the material. Soil applied materials require cool, wet or good soil moisture conditions for optinum life and activity. Wind is very important and is generally considered because it is very obvious the effect it has on application.

Type of Application

The type of application should fit the situation. Spot treatment or banding should be used in preference to broadcast. Less cost is involved with spot treatment or banding, even when more expensive materials are used. Also, there are more materia available for use as spot treatments rather than broadcast. The use of granuals should not be overlooked for spot or even broadcast treatments on fields where considerable

trash is present. If a liquid material is the type that becomes inactive quite readily if not incorporated soon after application, a granular material could be considered to give more time for incorporation.

When broadcast treatments are made, you should know all the plants within the area to be treated and how the treatments will affect them. Broadcast treating is essential in some crops, such as small grains. When broadcast treating know your equipment and the exact rate you are applying.

Cost

Cost is usually the first thing that is taken into account. Yes, it is important but often the cost of the herbicide is all that is taken into account. The return, if the material is used right, in most instances will out-weigh the material cost. For example, if a field of winter wheat is infected with field gromwell and yields 20 bushels per acre without treatment and 32 bushels when treated for a cost of $ 3.00 to $ 3.50 per acre, then it can readily be computed that this investment can return 12 bushels of wheat per acre. Even at $ 1.00 per bushel for grain this is a good return for spraying. In other words, although the cost of treatment may be high it is the projected return or profit that should be considered.

Table for converting pounds per gallon active acid to ounces or pints from container

Rate - Active		One Pound Active Material per Gallon		Two Pounds Active Material Per Gallon		Four Pounds Active Material Per Gallon	
oz/A	#/A	Fluid ounces from container per acre	Pints from container per acre	Fluid ounces from container per acre	Pints from container per acre	Fluid ounces from container per acre	Pints from container per acre
1	.06	8	1/2	4	1/4	2	1/8
2	.12	16	1	8	1/2	4	1/4
3	.19	24	1 1/2	12	3/4	6	3/8
4	.25	32	2	16	1.0	8	1/2
5	.31	40	2 1/2	20	1 1/4	10	5/8
6	.37	48	3	24	1 1/2	12	3/4
7	.44	56	3 1/2	28	1 3/4	14	7/8
8	.50	64	4	32	2.0	16	1.0
9	.56	72	4 1/2	36	2 1/4	18	1 1/8
10	.62	80	5	40	2 1/2	20	1 1/4
11	.69	88	5 1/2	44	2 3/4	22	1 3/8
12	.75	96	6	48	3.0	24	1 1/2
13	.81	104	6 1/2	52	3 1/4	26	1 5/8
14	.87	112	7	56	3 1/2	28	1 3/4
15	.94	120	7 1/2	60	3 3/4	30	1 7/8
16	1.00	128	8	64	4.0	32	2.0
17	1.06	136	8 1/2	68	4 1/4	34	2 1/8
18	1.12	144	9	72	4 1/2	36	2 1/4
19	1.19	152	9 1/2	76	4 3/4	38	2 3/8
20	1.25	160	10	80	5.0	40	2 1/2
21	1.31	168	10 1/2	84	5 1/4	42	2 5/8
22	1.37	176	11	88	5 1/2	44	2 3/4
23	1.44	184	11 1/2	92	5 3/4	46	2 7/8
24	1.50	192	12	96	6.0	48	3.0
25	1.56	200	12 1/2	100	6 1/4	50	3 1/8
26	1.62	208	13	104	6 1/2	52	3 1/4
27	1.69	216	13 1/2	108	6 3/4	54	3 3/8
28	1.75	224	14	112	7.0	56	3 1/2
29	1.81	232	14 1/2	116	7 1/4	58	3 5/8
30	1.87	240	15	120	7 1/2	60	3 3/4
31	1.94	248	15 1/2	124	7 3/4	62	3 7/8
32	2.00	256	16	128	8.0	64	4.0

Table for converting pounds per gallon active acid to teaspoons from container per 1000 sq. ft.

Rate - Active		One Pound Active Material per Gallon		Two Pounds Active Material per Gallon		Four Pounds Active Material per Gallon	
oz/A	#/A	Fluid ounces from container per 1000 sq. ft.	Teaspoons from container per 1000 sq. ft.	Fluid ounces from Container per 1000 sq. ft.	Teaspoons from container per 1000 sq. ft.	Fluid ounces from container per 1000 sq. ft.	Teaspoons from container per 1000 sq. ft.
1	.06	.2	1	.1	.5	.1	.3
2	.12	.3	2	.2	1	.1	.5
3	.19	.5	3	.3	2	.1	.8
4	.25	.7	4	.3	2	.2	1.1
5	.31	1	6	.5	3	.2	1.4
6	.37	1.2	7	.5	3	.3	1.6
7	.44	1.3	8	.7	4	.3	1.9
8	.50	1.5	9	.7	4	.4	2.2
9	.56	1.7	10	.8	5	.4	2.5
10	.62	1.8	11	1	6	.4	2.7
11	.69	2.0	12	1	6	.5	3.0
12	.75	2.2	13	1.2	7	.5	3.3
13	.81	2.3	14	1.2	7	.6	3.6
14	.87	2.5	15	1.3	8	.6	3.8
15	.94	2.7	16	1.3	8	.7	4.1
16	1.00	2.8	17	1.5	9	.7	4.4
17	1.06	3.2	19	1.5	9	.8	4.6
18	1.12	3.3	20	1.7	10	.8	4.9
19	1.19	3.5	21	1.7	10	.9	5.2
20	1.25	3.7	22	1.8	11	.9	5.5
21	1.31	3.9	23	2.0	12	1.0	5.7
22	1.37	4.0	24	2.0	12	1.0	6.0
23	1.44	4.2	25	2.2	13	1.1	6.5
24	1.50	4.3	26	2.2	13	1.1	6.5
25	1.56	4.5	27	2.3	14	1.1	6.8
26	1.62	4.7	28	2.3	14	1.2	7.1
27	1.69	4.8	29	2.5	15	1.2	7.4
28	1.75	5.2	31	2.5	15	1.3	7.6
29	1.81	5.3	32	2.7	16	1.3	7.9
30	1.87	5.5	33	2.7	16	1.4	8.2
31	1.94	5.7	34	2.8	17	1.4	8.5
32	2.00	5.8	35	3.0	18	1.5	8.7

Table for converting dry material to teaspoons, ounces & pounds from container

ate - Active		1 % Active Ingredient			50 % Wettable Powder			80 % Wettable Powder		
z/A	#/A	From container per 1000 sq. ft. oz	tsp	lbs. from container per Acre	From container per 1000 sq. ft. oz.	tsp.	lbs. from container per Acre	From container per 1000 sq. ft. oz.	tsp	lbs. from container per Acre
2	.125	4.3	26	12.5	.1	.5	.250	.1	.3	.1563
4	.250	8.8	53	25.0	.2	1.0	.500	.1	.7	.3125
6	.375	13.1	79	37.5	.3	1.5	.750	.2	1.0	.4688
8	.500	17	102	50.0	.4	2.0	1.000	.2	1.0	.6250
10	.625	22	132	62.5	.4	2.5	1.250	.3	1.5	.7813
12	.750	26	156	75.0	.5	3.0	1.500	.3	2.0	.9375
14	.875	31	186	87.5	.6	3.5	1.750	.4	2.0	1.0938
16	1.000	35	210	100.0	.7	4.0	2.000	.4	2.5	1.250
18	1.125	39	234	112.5	.8	4.5	2.25	.5	3.0	1.4063
20	1.250	44	264	125.0	.9	5.0	2.50	.6	3.0	1.5625
22	1.375	48	288	137.5	1.0	6.0	2.75	.6	3.5	1.7188
24	1.500	52	312	150.0	1.1	6.0	3.00	.7	4.0	1.8750
26	1.625	55	330	162.5	1.1	7.0	3.25	.7	4.0	2.03125
28	1.750	61	366	175.0	1.2	7.0	3.50	.8	4.5	2.1875
30	1.875	65	390	187.5	1.3	8.0	3.75	.8	5.0	2.3438
32	2.000	70	420	200.0	1.4	8.5	4.00	.9	5.0	2.5000
34	2.125	74	444	212.5	1.5	9.0	4.25	.9	5.5	2.656
36	2.250	79	474	225.0	1.6	9.5	4.50	1.0	6.0	2.8123
38	2.375	83	498	237.5	1.7	10	4.75	1.0	6.0	2.9688
40	2.500	87	522	250.0	1.8	10.5	5.00	1.1	6.5	3.125
42	2.625	92	552	262.5	1.8	11.0	5.25	1.2	7.0	3.2813
44	2.750	96	576	275.0	1.9	11.5	5.50	1.2	7.0	3.438
46	2.875	100	600	287.5	2.0	12.0	5.75	1.3	7.5	3.594
48	3.000	105	630	300.0	2.1	12.5	6.00	1.3	8.0	3.750
50	3.125	109	654	312.5	2.2	13.0	6.25	1.4	8.0	3.9063
52	3.250	113	678	325.0	2.3	13.5	6.50	1.4	8.5	4.0625
54	3.375	118	708	337.5	2.4	14.0	6.75	1.5	9.0	4.2188
56	3.500	122	732	350.0	2.5	14.5	7.00	1.5	9.0	4.375
58	3.625	126	756	362.5	2.5	15.0	7.25	1.6	9.5	4.5313
60	3.750	131	786	375.0	2.6	15.5	7.50	1.6	10.0	4.6875
62	3.875	135	810	387.5	2.7	16.0	7.75	1.7	10.0	4.8438
64	4.000	140	840	400.0	2.8	17.0	8.00	1.8	10.5	5.000

Presented at
Montana Herbicide Workshops
October 12-20, 1972

VOLATILITY AND DRIFT OF HERBICIDES

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Off-target damage to plants near an area treated with herbicides often has been ascribed to volatility of the herbicide. In some cases, the cause was drift of fine spray particles at the time of application. Distinguishing between the action of volatilization and drift in movement of herbicides off the target is very important. The vaporization potential of a herbicide is based on the form or molecular structure of the active ingredient, and an applicator can only select the proper formulation. Drift is almost entirely a result of the application conditions, most of which can be controlled or adjusted to by the operator. Many of the problems created by both involve nearly or actually invisible particles. The sources of these particles and the method of their formation may vary greatly and we need to be aware of these differences and what can be done about relieving their off-target impact.

DRIFT is that part of the spray that moves off the target in fine particles broken up by the nozzles or air impact at the time of application. VOLATILIZATION of herbicides is the escape of molecules from spray drops while falling or from surfaces anytime after application. We will show how to separate the two actions, although, on occasion, off-target effects may result from both sources.

VOLATILITY

All chemicals have a vapor pressure. The level determines whether a particular herbicide could volatize sufficiently under certain high temperature conditions to move off in amounts that would cause off-target problems.

A number of common herbicides are listed in Table 1, showing their relative volatility. You may note that some soil fumigants are included. They are herbicidal and depend on vaporization to move through the soil. Certain herbicides, like cycloate (Ro-Neet), Eptam, trifluralin (Treflan), etc., can be lost through volatilization if not incorporated soon after application. They usually do not cause off-target damage. Contact agents, such as dinoseb, can cause damage from drift, but are very unlikely to volatize sufficiently to affect even nearby plants or cause illegal residues. Our discussion will be concerned mostly with the herbicides that are likely to cause off-target problems by vaporization or drift.

The form of the herbicide may change the vapor pressure, such as the salt vs. ester forms of 2,4-D; even the esters vary greatly in their volatility. We can determine the tendency for a herbicide to volatize by observing its vapor pressure, but these figures may not always be available. Since it is relative, we need to have a base that is known to have very low vapor pressure and does not volatize sufficiently to cause a problem. The hormone type herbicides have been formulated to provide essentially non-volatile, "low" volatile and "high" volatile forms to enable the user to select the form most suitable to his needs. The ester forms are usually more herbicidal than the salts or are effective over a wider range of conditions. The metal, ammonium and amine salts of 2,4-D, 2,4,5-T, silvex and MCPA are examples of essentially non-volatile products. The low volatile (LV) esters of the phenoxy herbicides would not volatize readily at lower temperatures, but the high volatile esters would vaporize easily at almost any temperatures at which they would be applied. The high volatile esters include the methyl, ethyl, isopropyl, butyl and amyl esters, all considered short carbon chains. Low volatile esters have been chosen to maintain the efficacy imparted by the high volatile ester of the herbicide as well as reduce vaporization potential; they include isooctyl, hexylethyl, butoxy ethanol, propylene glycol butyl ether and others with longer carbon chains.

TABLE 1. Relative Volatility of Various Herbicide Products

Product	Relative Volatility
2,4-D, 2,4,5-T, MCPA, Silvex:	
Water Soluble Salts	Very Low
Low Volatile Esters	Low
High Volatile Esters	High
Oil Soluble Amine Salts	Very low
Alachlor (Lasso)	Low
Amino triazole (Amitrole, Cytrol)	Very low
Atrazine (Aatrex)	Very low
Bromacil (Hyvar)	Very low
Bromoxynil (Brominal, Buctril)	Very low
Dalapon (DOWPON®)	Very low
Dicamba, amine (Banvel)	Very low
Dinoseb:	
Water Soluble Salts (PREMERGE®, Sinox P.E., Dow Selective)	Very low
Phenol (Dow General, Sinox)	Low
Diuron (Karmex)	Very low
Nitralin (Planavin)	Medium
Paraquat	Low
Picloram (TORDON® herbicides), various salts	Very low
Simazine	Very low
Trifluralin (Treflan)	Medium
1,3-Dichloropropene (TELONE®, DD)	Very high
Methyl Bromide (MC-2)	Extremely high

®Registered trademark of The Dow Chemical Company, Midland, Michigan.

Some workers wanted to test the phenoxy forms in actual field situations. Day et al. established several plots in a cotton field in the Imperial Valley of California to test the volatilization of the acid, low volatile esters and amine salts of 2,4-D and a low volatile ester of silvex. Ten foot squares were treated with rates of 4 lbs. active per acre, except for one ester product used at 2 to 16 lbs./A. The air temperature during this period--July and August--averaged 103°F, with a maximum of 117°F. The soil temperature under shade averaged 108°, with variations to 129°F. In the sun, the average surface soil temperature was 138°F with a maximum of 158°F. Figures 1a and 1b show the results 10 days and 65 days after application in degrees of injury to cotton; Table 2 shows the formulations and rates used.

TABLE 2. Formulations of 2,4-D and Rates of Application to Experimental Plots in a Coachella Valley Cotton Field 1954

Plot No.	Formulation	Rate, lbs./acre (in 100 gal.)
1	Butoxyethanol 2,4-D[1]	16
2	Butoxyethanol, 2,4-D[1]	8
3	Butoxyethanol 2,4-D[1]	4
4	Propyleneglycol butyl ether,2,4-D[2]	4
5	Tetrahydrofurfuryl 2,4-D[3]	4
6	Butoxyethnaol 2,4-D[1]	2
7	Alkanolamine salts of 2,4-D[4]	4
8	Butoxyethanol 2,4-D[1]	1
9	2,4-D acid emulsion[5]	4
10	Propyleneglycol butyl ether 2,4,5-TP[6]	4

[1]Weedone LV-4, supplied by the American Chemical Paint Co. --From Day et al., 1959

[2]Esteron Ten-Ten, supplied by The Dow Chemical Company.

[3]Estercide D-4, supplied by the California Spray Chemical Corp.

[4]Formula 40, supplied by The Dow Chemical Company.

[5]Weedone 638, supplied by the American Chemical Paint Co.

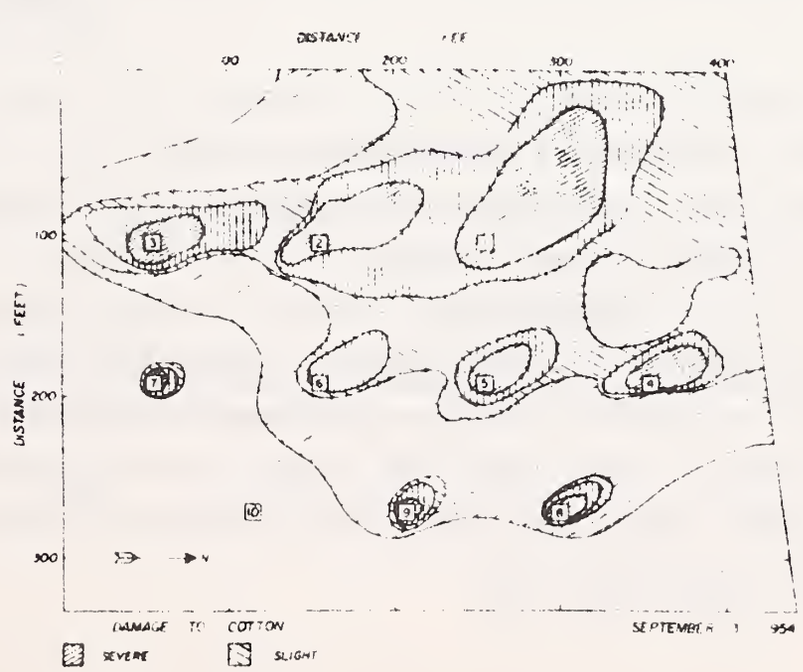
[6]Kuron A, supplied by The Dow Chemical Company.

FIGURE 1A

Diagram showing degree and extent of injury to plants in a Coachella Valley cotton field 37 days after application of herbicides to 10' square experimental plots.

FIGURE 1B

Diagram showing degree and extent of injury to plants in a Coachella Valley cotton field 65 days after application of herbicides to 10' square experimental plots. Note the delayed appearance of symptoms around the plot (No. 7) treated with alkanolamine salts of 2,4-D (in comparison to Fig. 1A).



--From Day, et al., Hilgardia 28(11):261, 1959.

These were extreme conditions, but they show the problems that can develop on sensitive crops from low volatile forms of 2,4-D. The acid form moved much less than did the LV esters and the alkanolamine salt moved a very little bit; this showed up between 37 and 65 days later. The LV ester of silvex showed some early movement but the effect in 65 days was nil.

Another test by Grover et al. in Southern Canada separated the movement of DMA salt and butyl ester of 2,4-D in the vapor vs. the drift form. They used 0-3 min. settling time for the drift particles and a 30 min. limit for vapor collection. Ground and air samples were collected downwind. Table 3 shows the amounts found in each category. Drift was the same for both forms; and the butyl ester volatized readily whereas there was none from the salt.

TABLE 3. Recoveries of 2,4-D (dimethylamine and butyl ester) as Droplets and in Vapor Form

Form of 2,4-D	Expt. No.	Droplet 0-3 min.	Vapor	
			0-3 Min.	0-30 min.
		(%)	(%)	(%)
Amine	1	3	0	0
	2	4	0	0
Ester	1	(3.5)	11	30
	2	(3.5)	14	26

--From Grover et al., 1972
WEED SCIENCE 20(4):323.

The high volatile esters are considered too volatile and are prohibited in many areas. Freed found that grain sprays of isopropyl or ethyl esters of 2,4-D could be found in the air many miles from the spraying site. The "low" volatile esters usually will not vaporize enough to cause off-target damage; we consider that, where air temperatures are over about 90°F for several days there is a chance that nearby plants may be affected. This is most likely if large areas are treated and the air moves continuously from the treated area toward susceptible plants, as in the study in the Imperial

Valley. Since salts of these herbicides are very low in volatility, they are considered very unlikely to cause off-target damage from that source, but drift is a possibility. This applies to water- and oil-soluble amine salts and metal and other salts. Selection of the proper form will be indicated by the relative efficacy for the desired use and vaporization potential in the particular area.

DRIFT

Herbicides can be applied by air using fixed wing aircraft of different sizes, from a Cub (high wing monoplanes) to a Stearman (bi-plane) or a 4-engine B-17 type, or helicopters of different sizes. Ground application can include hand-guns at low or high pressure, booms on sprayers, fixed nozzles that throw to 25' and air carriers (mist blowers) either backpack types or several sizes of truck or trailer mounted units that can treat up to 90' swaths. Generally more drift occurs from aerial application, but the details of equipment and air conditions must be assessed to predict, with more certainty, the actual degree of drift in any particular situation.

The magnitude of the drift problem can be demonstrated by the results of applying DDT on alfalfa in a California experiment. One-half pound per acre was applied in 8 gal. spray by a Stearman 3-5' above the crop, making 20 passes on a 40 acre field with a 3-6 mph crosswind. Hay samples were taken at intervals from 100 to 4000 feet downwind and analyzed for DDT. The results are shown in Table 4.

TABLE 4. Spray Drift Residue on Alfalfa from 20 Swaths or 40 Acres on a One-half Mile Run

Stability Ratio $T_{32} - T_{8}$ °F	Spray Atomization	Chemical Residue, PPM					
		Feet Downwind					
		100	200	400	1000	2000	4000
+4°F	Fine	0.95	0.94	0.69	0.38	0.18	0.06
+4°F	Fine	0.68	0.3	0.15	0.05	0.016	0.007

--From Akesson & Yates, Ann. Rev. Entom., 1964

You can see that detectable amounts of pesticide are found up to 4000' downwind, under some conditions.

The use of dusts to carry herbicides has been discontinued largely so the tremendous drift from this type of carrier will not be considered. Granular carriers present little drift problems, so these will also be omitted.

Serious loss of herbicide activity can occur before reaching the target, especially with aerial applications. Tests have shown that as much as 50 to 75% of the active ingredient has been unaccounted for from aerial applications. This can lead to both reduced benefit in pest control and increasing aerial or other off-target contamination. Reducing drift can help reduce these losses and at least retain most of the intended activity.

Herbicides require certain coverage or drops per square inch for the most efficient phytotoxicity effect; the coverage requirements vary with the individual herbicide as well as adjuvants such as oil or surfactants. Several researchers have shown that phenoxy herbicides increase in activity on leaves up to a density of about 70 per square inch. The size of the spot or drop can be invisible. Very little increase in efficiency is realized with better coverage. Picloram, amitrol and dicamba are translocated more readily in plants and it is possible that fewer spots are required. Contact herbicides usually need full coverage. We know that drift is increased with fine droplets and efficacy is also improved. Our objective as applicators is to use the volume rates and spray break-up that will provide good control with minimum drift hazard. Sometimes this may mean not making the application. Helicopter or aerial applicators have sat for days or weeks to await safe weather conditions to prevent drift.

The movement of fine spray particles off the target area, which we defined as "DRIFT" is dependent on a large number of influences which are itemized for aerial application in Table 5. Ground applications are affected similarly but to a lessor degree or the relative importance of the different factors is changed.

TABLE 5. Factors Affecting Drift of Aerially Applied Herbicides

1. Herbicide - Nature and Rate
2. Nature and volume rate of carrier.
3. Spray drop size spectrum, as affected by:
   a. Nozzle type, capacity or pressure.
   b. Nozzle orientation to airstream.
   c. Boom location cf. wing or rotor.
   d. Speed of aircraft.
   e. Viscosity.
4. Application conditions:
   a. Flight path - Level, rising, falling or turning.
   b. Height of release.
   c. Wind speed and direction.
   d. Air stability (vertical movement).
   e. Width of swath.
   f. Number of passes.
5. Distance and direction to problem areas.
6. Screening effect of barriers - Trees, etc.
7. Turning area and technique.

Droplet size is very important; you can see the relative size of water droplets in various components of the atmosphere in Table 6. Note that the droplets in the size range of 30 μ or smaller remain suspended (fog); in herbicide sprays, these droplets may be nearly invisible in the air. Of course, these, as well as larger droplets, are subject to any air movement. The larger droplets are moved horizontally less, but still may move considerable distances; note that 100 μ droplets can move 48' in a 3 mph wind while falling 10'.

TABLE 6. Spray Droplet Size and Its Effect on Spray Drift

Drop Diameter Microns[1/]	Particle Type	Weather Elements	Distance Moved by 3 MPH Wind in 10' Fall
400	Coarse aircraft spray	Light rain	8.5'
150	Medium aircraft spray	Mist	22'
100	Fine aircraft spray		48'
50	Air carrier spray		178'
20	Fine sprays & Dusts	Fog	1,109'
10	Usual dusts & Aerosols		4,435'
2	Aerosols		21 miles

[1/] A micron (u) is about 1/25,000 inch.

--From Akesson & Yates, Ann. Rev. Entom., Vol. 9, 1964.

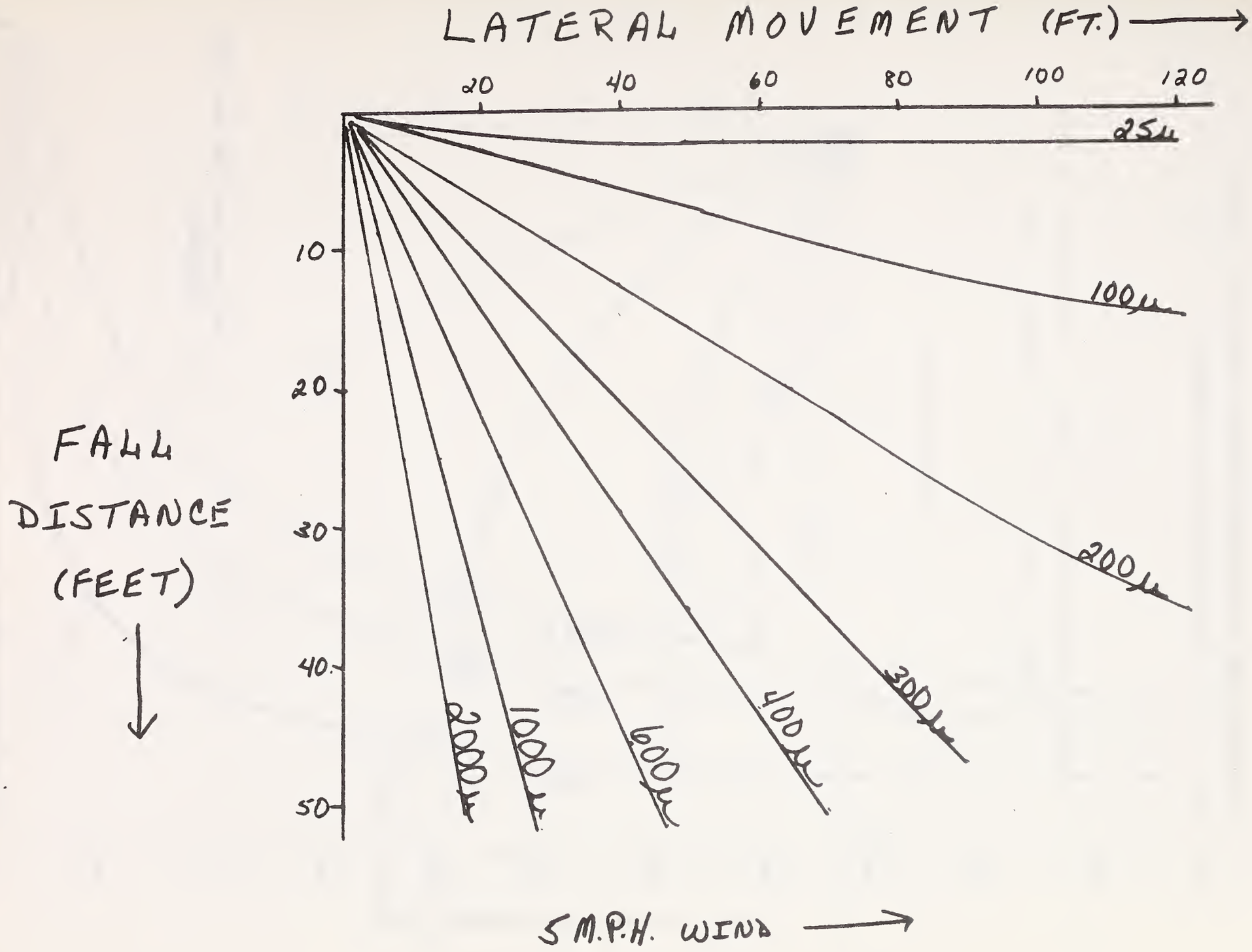
Fig. 2 shows the effect of a 5 mph crosswind on horizontal displacement of different size drops. This assumes no change in size during fall.

Research has shown that there is a rapid decrease in drift potential of drops as they are increased from 20 to about 150 to 200 μ. Thereafter, as the drops enlarge, there is not much change in the drift potential. The critical size where this difference occurs is higher with higher wind speeds, but lies in the range of 150 to 250 μ for speeds of 1 to 8 mph (Courshee, Byrd); a graph in Fig. 3 shows this relationship.

To decrease drift by changing drop size, we gain greatly by increasing drop sizes to about 150 to 250 μ, and not much after that. This size range allows adequate coverage with reasonable volume rates and is a good size to seek for herbicidal sprays.

With water carriers, drop size may decrease during fall because of evaporation unless an invert emulsion is used. Droplets falling in to air of relative humidity less than about 80% may evaporate before hitting the target and become much smaller or even disappear. Fig. 4 shows the effects

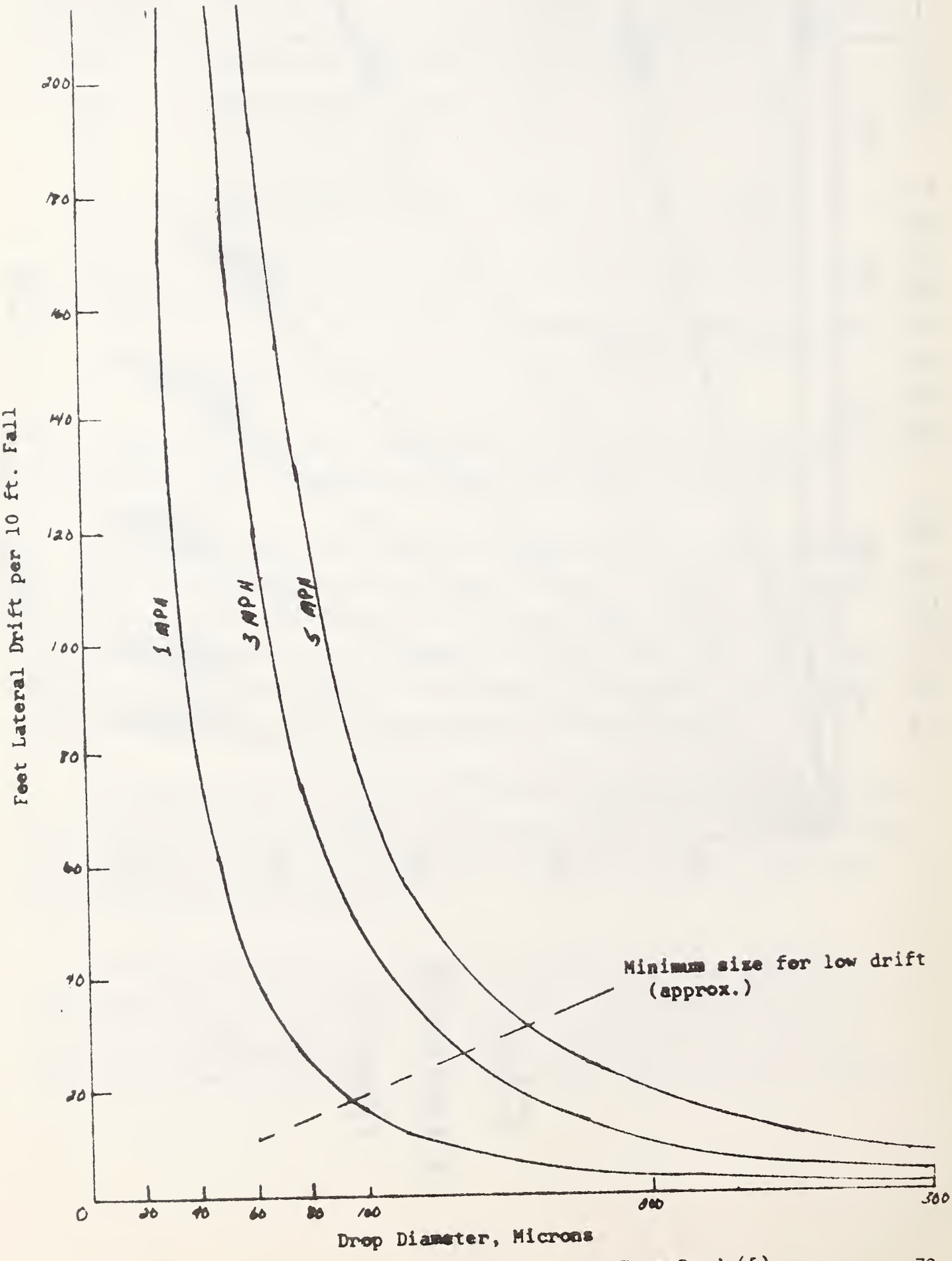
FIGURE 2



--From Seymour (unplublished data)

FIGURE 3

Linear Plot of Relation of Spray Drop Size to Drift at Different Wind Speeds

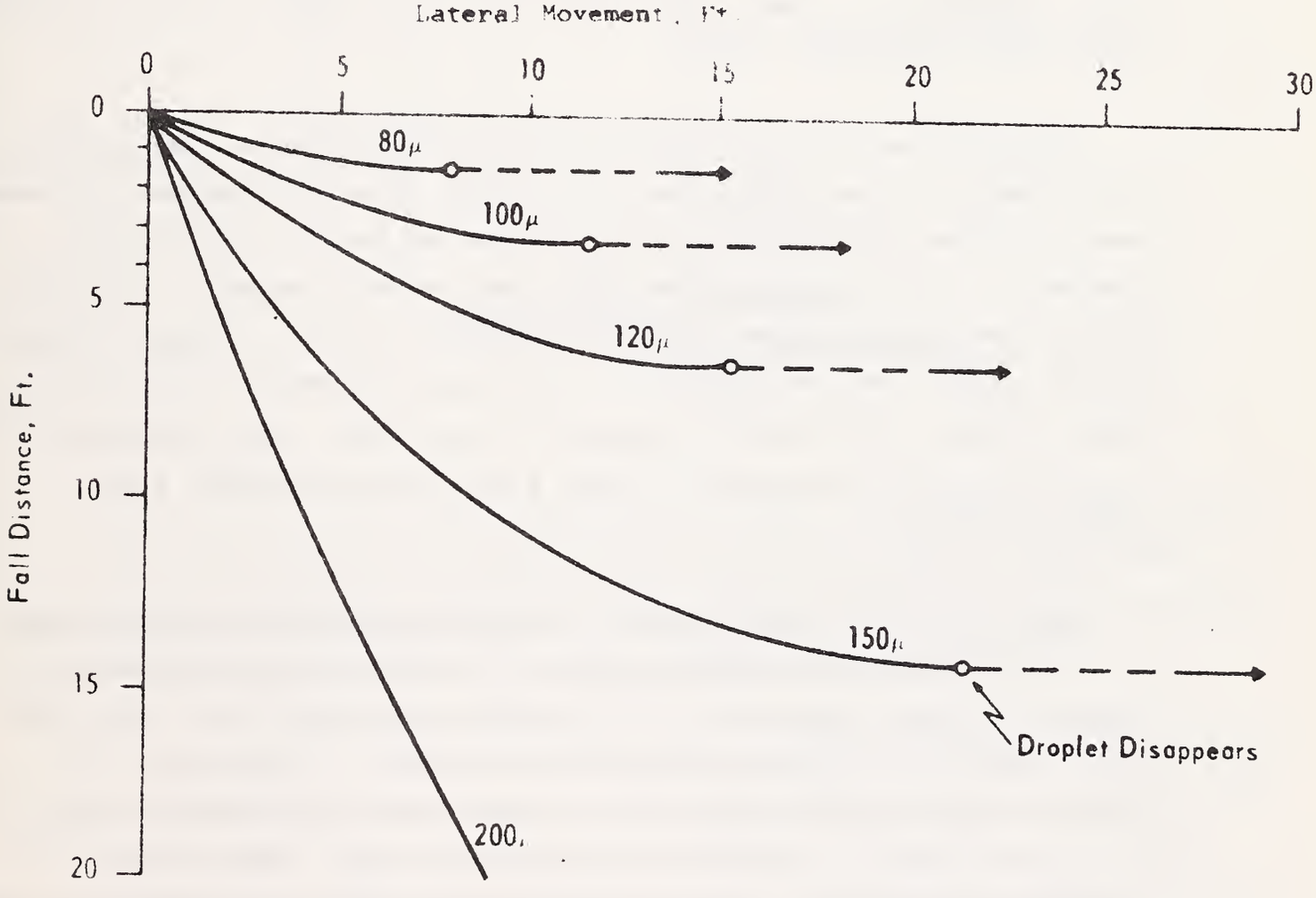


--From Byrd (5)

of evaporation on water droplets 80 to 200 μ falling through air with a 50% relative humidity. Some lateral movement was induced by a 1 mph cross-wind.

FIGURE 4

Effect of Evaporation on Lateral Movement of Water Droplets Falling through Air at 50% Relative Humidity



50% Relative Humidity, Wind = 1 mph

Note that the 80 to 120 μ drops disappeared in less than 10' drop. The 200 μ drops may survive to the ground, but will certainly be smaller and more subject to drift. It is evident, then, that as water droplets fall through air with a water deficit (less than 100% RH), they will be decreasing in size and will move according to the drift graph shown previously. Addition of oils or surfactants should reduce this loss, but they also induce production of finer droplets.

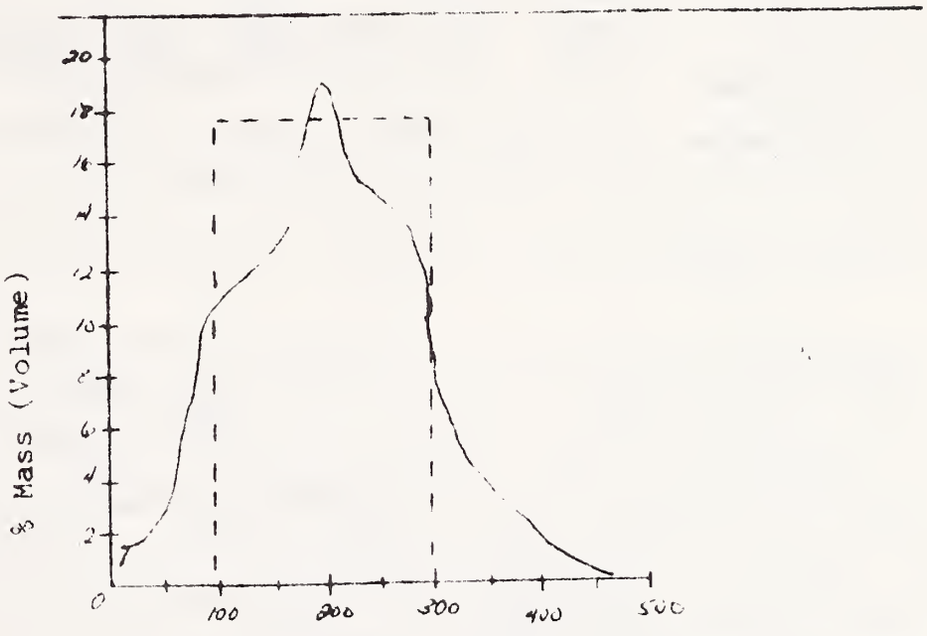
The factors that affect droplet size as the sprays are produced include herbicide formulation, carrier (water, oil, surfactant), viscosity, nozzle construction, shear at the orifice, and air impact. We will discuss spray droplet production first.

As liquids are forced through orifices under pressure, they speed up. There usually is some turbulence in the nozzle or spray dispenser that exerts break up forces on the liquid. As it leaves the nozzle it is usually directed in a fan or cone pattern that also creates stresses. The liquid extends into sheets--either flat or circular--or threads. Highly stressed liquids develop waves in the sheets or threads, and break up resulting in larger droplets. The stress is caused by the pressure and turbulence, such as internal deflecting vanes to induce a cone or any deviation from a circular orifice.

When a liquid is forced apart, it invariably forms some larger drops with several satellite smaller droplets. It will be very difficult and unusual to produce sprays with a very narrow size range in the field, and nearly impossible to produce sprays with "no drift". Most nozzles or spray devices produce a distribution of drop size, as indicated in Fig. 5. The pattern shown by the dashed lines would be ideal. Some nozzles will produce wider ranges of drop sizes than others. This is related to the nozzle orifice shape. A flat fan will produce more fines than will a solid stream or jet. The full jet (solid cone) type will give less drop size variation than will a solid cone with the D-series, which has a central hole in the

FIGURE 5

Distribution of Spray Droplet Sizes



--From Sexsmith et al.

swirl plate. Off-center nozzles will produce a wide range of drop sizes. A rough estimate can be made of the relative potential for fine drops by noting the extent of deviation of the orifice from a round hole, the turbulence induced inside the nozzle and variation in shape.

Because of this range of drop size, various methods are used to designate this factor. The one used most is probably a size at which half the spray volume is in drops above and half below the figure; it is called "mean volume diameter". This results in a much greater number of drops in the smaller 50%. Drop sizes also are measured by their diameter. Volume has a third dimension so drops with ½ diameter of others will have ¼ the volume of liquid. Or a volume of spray will produce 4 times as many 100 μ droplets as 200 μ drops.

Drop size is increased by increased flow rate, if other conditions are equal. This can be seen in terms of drop size in Fig. 6. This scale shows percent (%) by volume in each drop size. As the nozzle size is decreased, there is a decrease in average drop size. This will result in a similar increase in drift potential. Note also that drop size is decreased as pressure increases. There is, however, a different rate of drop size change as the flow changes. At higher flows, there is a greater effect of pressure than at low flows. This is true for other types of orifices as well. The effect of pressure from 25 to 100 psi is shown in Fig. 6 also.

Narrowing the fan or cone of a spray at equal pressure will increase drop size. The decrease in drop size with wider fans is plotted in Fig. 7 for a ? gpm flow at 40 psi. Changing from a 15° fan to a 65° fan decreased drop size from 2000 μ to 1000 μ. Narrowing the fan to 0° would further increase drop size. This applies to cones as well. Changing nozzles could have more effect on drop size than pressure variations, but experience has shown that pressures below 30 psi produce noticeably less drift. Actually, pressure is a variable that is easily controlled and any reduction in drift is welcome in certain situations.

As the spray leaves the nozzle it is subjected to impact by the air; in addition, the air force on the side of the spray may cause more break up. The latter force is not very important with ground application even from a vehicle moving 5 to 10 mph. At 10-20 mph, the effect of air is apparent. At 30 to 200 mph, the speeds employed by aerial applicators, the effects are very important; Table 7 (Isler and Carlton) shows the average drop size using a U-50120 nozzle (flat fan) at 25 psi at speeds from 80 to 200 mph. In this, as in tests with other nozzles, there was an inverse ratio of speed to drop size--a 2.5X change in air speed caused a 2.5X inverse change in drop size. It was the same whether the nozzle was pointed forward or backward, as shown in Fig. 8.

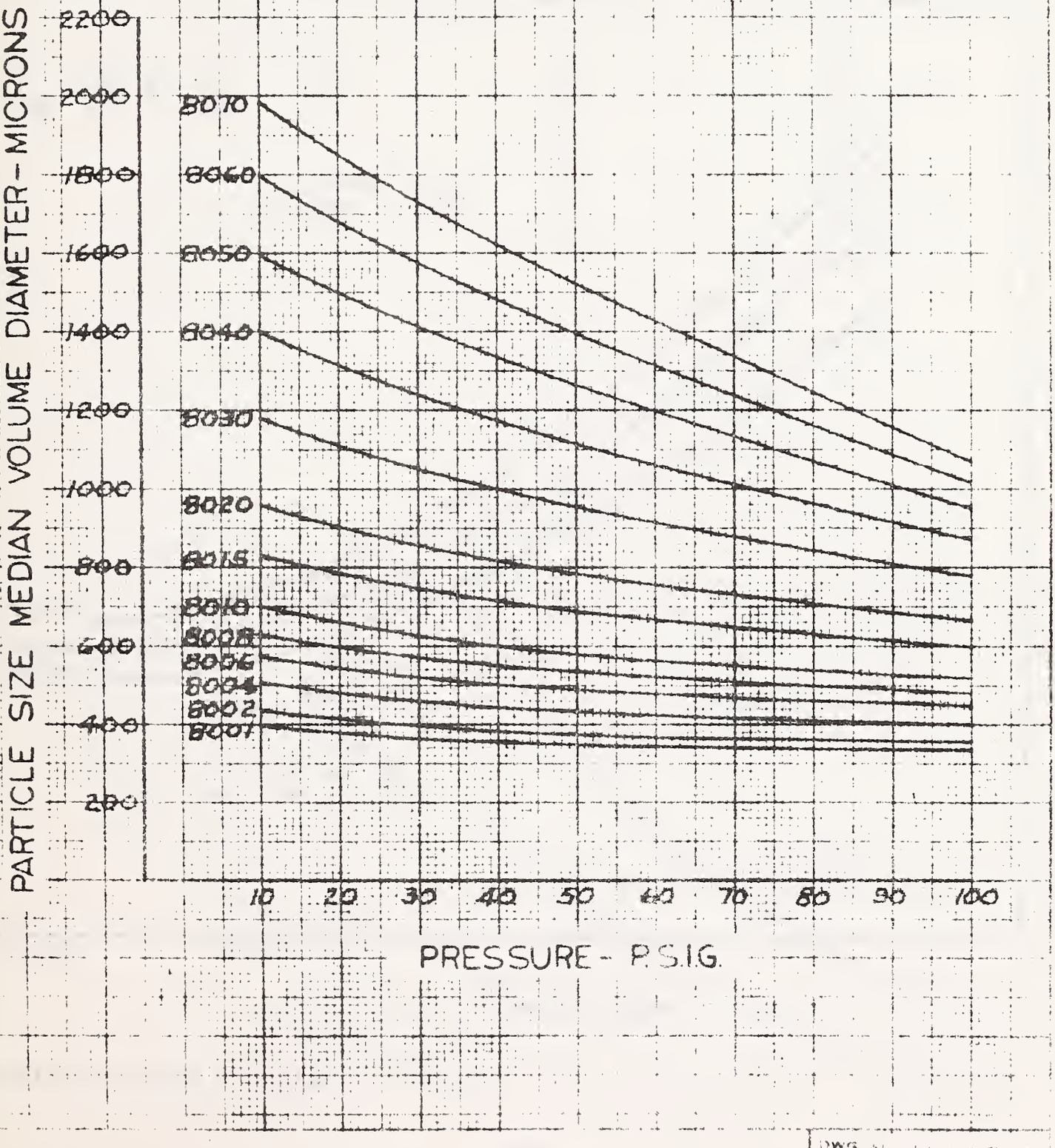
Changing the direction of the nozzle cf. the direction of flight was studied also, and results are shown graphically in Fig. 9 for 3 different size nozzles. The break up of spray is about twice as great from nozzles

FIGURE 6

SEPT. 27, 1966

SPRAY PARTICLE SIZE VS. PRESSURE

80° SERIES FLAT SPRAY NOZZLES
CAPACITIES 8001 THRU 8070
BASED ON WATER AT 70°F

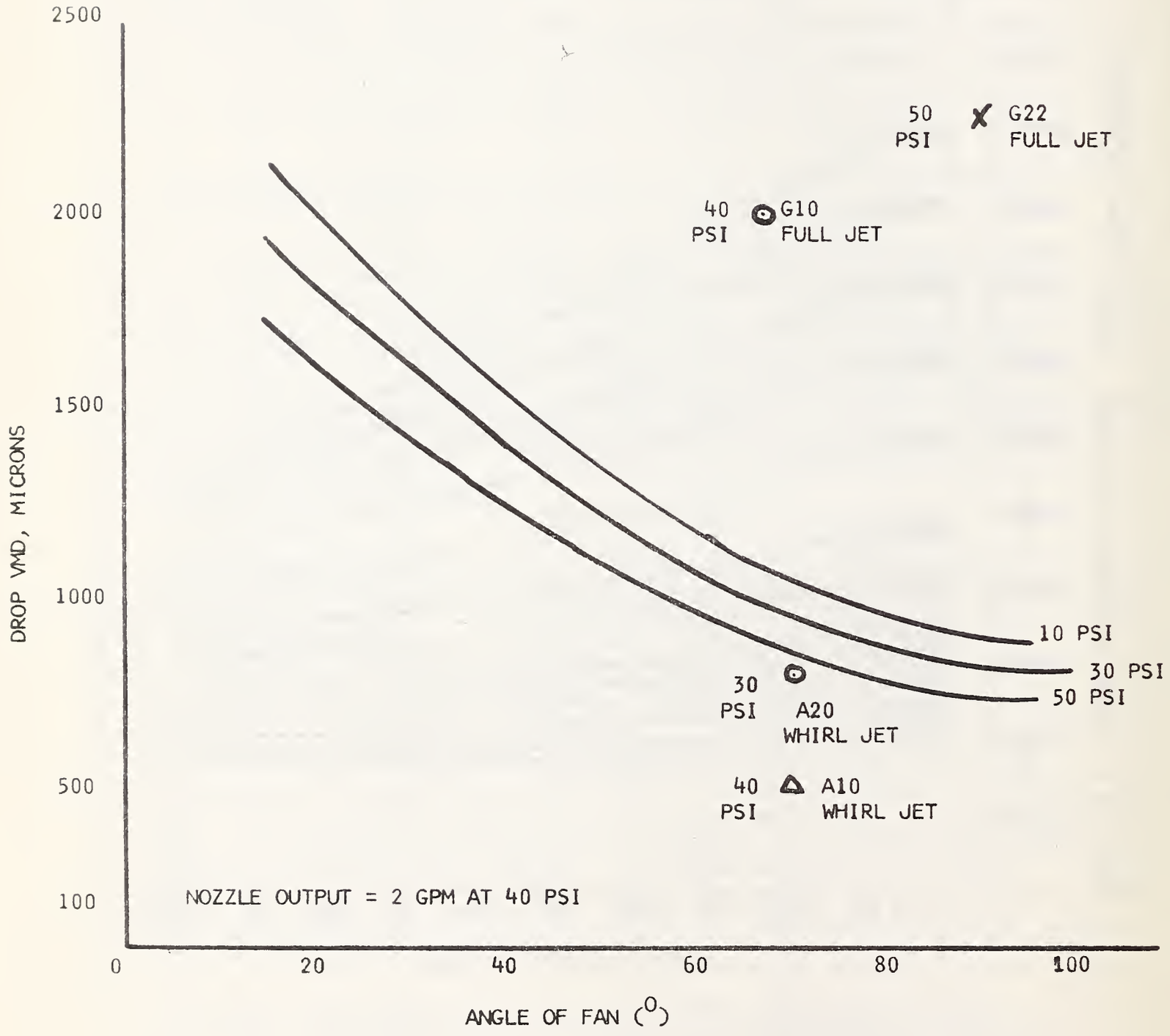


SPRAYING SYSTEMS CO. 3201 RANDOLPH ST.

DWG. 11825-5

FIGURE 7

RELATION OF PARTICLE SIZE (VMD) TO FLAT FAN NOZZLE ANGLE AND PRESSURE



DATA FROM SPRAYING SYSTEMS GRAP

TABLE 7. Effect of Aircraft [illegible] Spray

Nozzle Direction	Indicated Air Speed mph		Drop Size Microns	
Back & Down 45°	80	2.5%	324	2.5%
	120		226	
	150		169	
	200		127	
Forward & Down 45°	80	2.5%	232	2.5%
	120		160	
	150		125	
	200		[illegible]	

FIGURE 8

Effect of Airspeed on Atomization

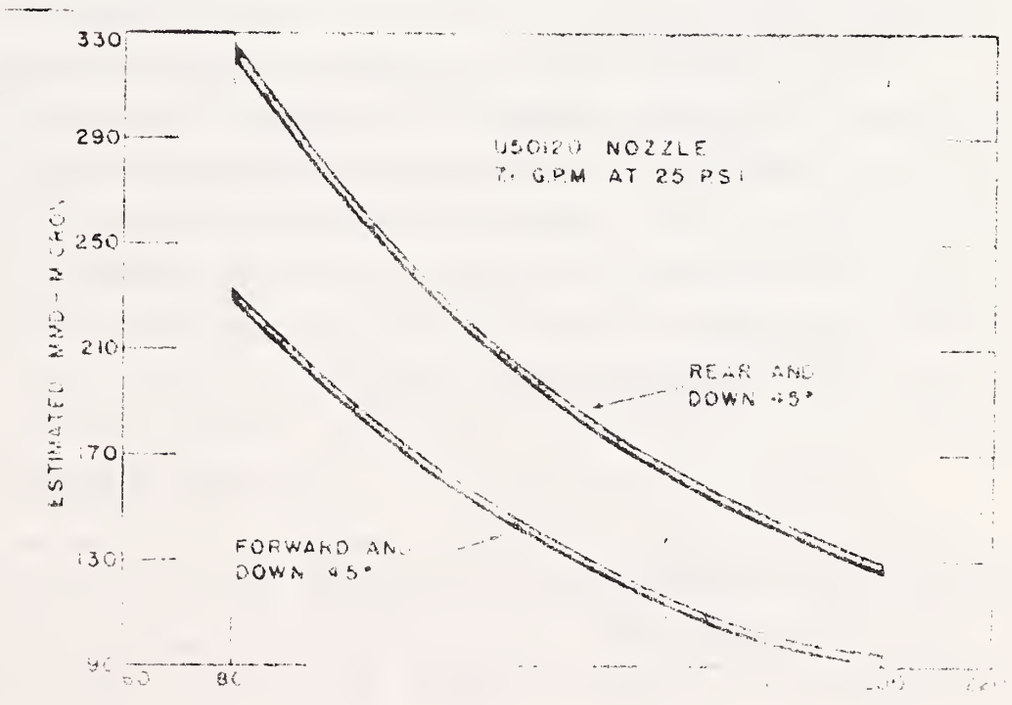
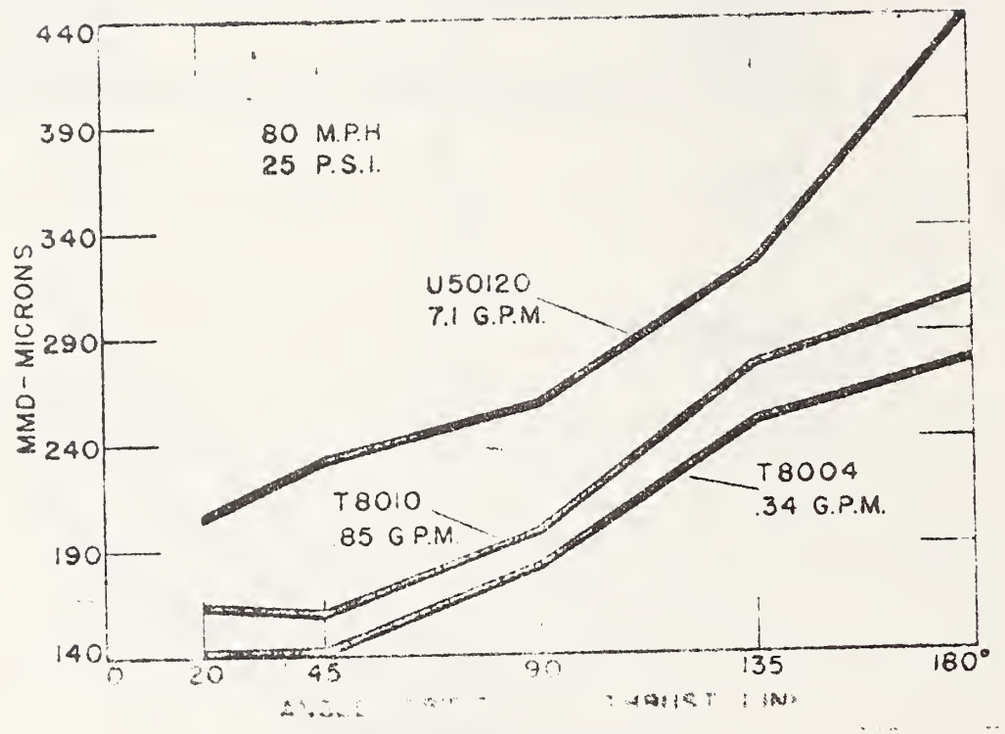


FIGURE 9

Effect of Orifice Direction and Size on Atomization

at 80 mph - Flat Spray Nozzles



pointing nearly forward (20° down) as those directed backward (180°). This effect has been found to be about the same with water carriers in research by Akesson and Yakes in California. Note the difference also in drop size cf. volume flow. The California regulations covering aerial application of 2,4-D and similar herbicides within certain injurious crop areas require round orifices no smaller than 1/16" diameter, pointed backwards and using pressure of less than 40 psi, except that helicopters at less than 55 mph can have nozzles down 90°.

The effect of formulation is usually that of the oil or surfactant factors or the particle size and concentration of wettable powders. Lowering the surface tension of water will allow formation of smaller droplets which usually increases drift. Using straight low viscosity oils, such as diesel, as a carrier will give noticeably more "fines" than water carriers. Tests

show that emulsifiable oil added to water carriers produce more fines with 10% by volume than with 2.8%. An oil soluble emulsifiable formulation or one with surfactants will therefore tend to decrease spray drop size and therefore increase drift.

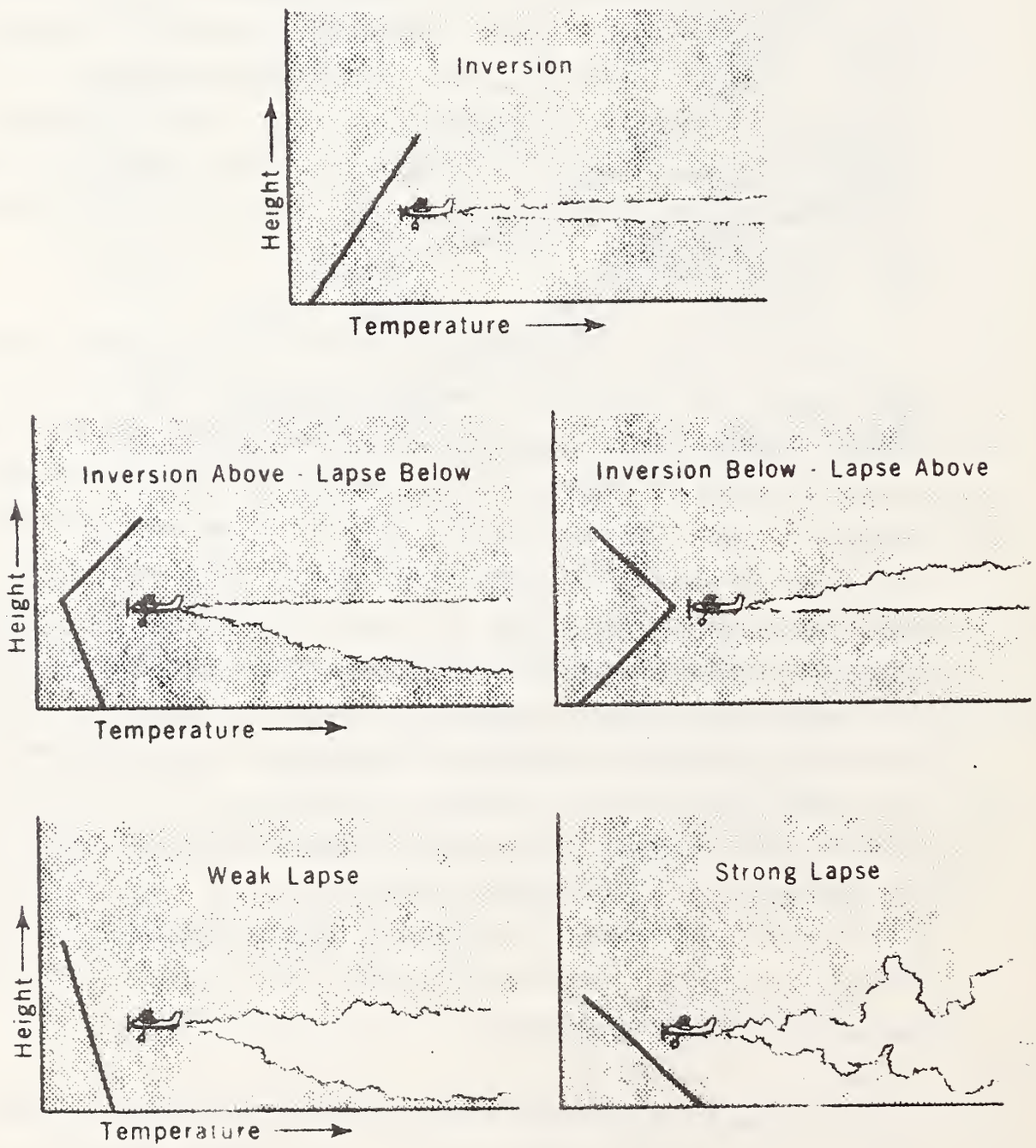
The other factor affecting drop size within the system is viscosity. It is found generally that, as viscosity increases, the drop size of sprays increase which can reduce drift. There are a number of viscosity modifying systems, including invert emulsions, hydroxyethylcellulose, a thixotropic wax and others, which will be explained later. Quite frequently these require changes in the pump, nozzle or other parts of the system; their characteristics and possible benefits should be considered carefully in relation to the drift control desired.

There are other effects of air on drift than the impact on spray. These include air stability, aircraft induced turbulence and boom location cf. the wing or rotor. Air stability is the tendency of the layers of air to stay in place vs. vertical mixing or simple rising in response to temperature. Ground applications are subject to the same influences of air stability, but not to the same degree as for aerial applications. The air stability is a function of the wind speed and the vertical temperature gradient. Normally vertical temperature decreases about 3.5° per 1,000 ft. This allows some vertical mixing. As you know, sometimes the air is warmer aloft than the normal reduction of temperature with elevation or even warmer than lower levels; this is called an inversion. The air tends to remain layered. The possible variations in temperature distribution vertically and effect on air stability are shown in Fig. 10. Any spray released below an inversion will remain in that zone; spray, especially fine particles, released above this inversion may remain aloft variously for long distances and settle through erratically.

Air stability has been assessed by the difference between the temperature at 8 and 32 feet above the soil. At a normal lapse rate, the temperature at 32' should be about 0.1°F cooler than at 8'. If it is warmer, an

FIGURE 10

Schematic, vertical profiles of fine spray (oil smoke) plumes released by plane under different thermal conditions.



--From Proc., Aerial Applic. Short Course, p. 144

inversion exists and the air is stable. Results of air stability on drift with 420 μ drops as actual deposits downwind from an aerial application of DDT are shown in Table 8 (p. 27). Note that there was 3 times as much drift at 100' under stable air as in unstable air. The difference was 10X more at 2000 feet. When the lower air heats up or it is stirred extensively, vertical mixing will occur and provide more deposits closer to the target (less drift).

Rising temperatures from sun heating the soil surface will cause the lower air to be forced upward. This can carry fine spray particles aloft. Many of you have noticed that aerial applications of herbicides on grain or sagebrush have been stopped when temperatures reach 70°F or some other level because the air rises variously and results in erratic deposits.

Air currents induced by the wings or rotors of aircraft can greatly affect drift. Even helicopter rotors have significant rotor tip vortices especially when forward speed is over about 25 mph. Fig. 11 (Akesson and Yakes, ASAE, pp. 66-104) shows a comparison between a Bell helicopter at 55 mph and a fixed wing craft at 80 mph. Note the difference between the right and left vortices on the helicopter. If any spray particles become entrained in these vortices, they can be carried aloft and be widely dispersed.

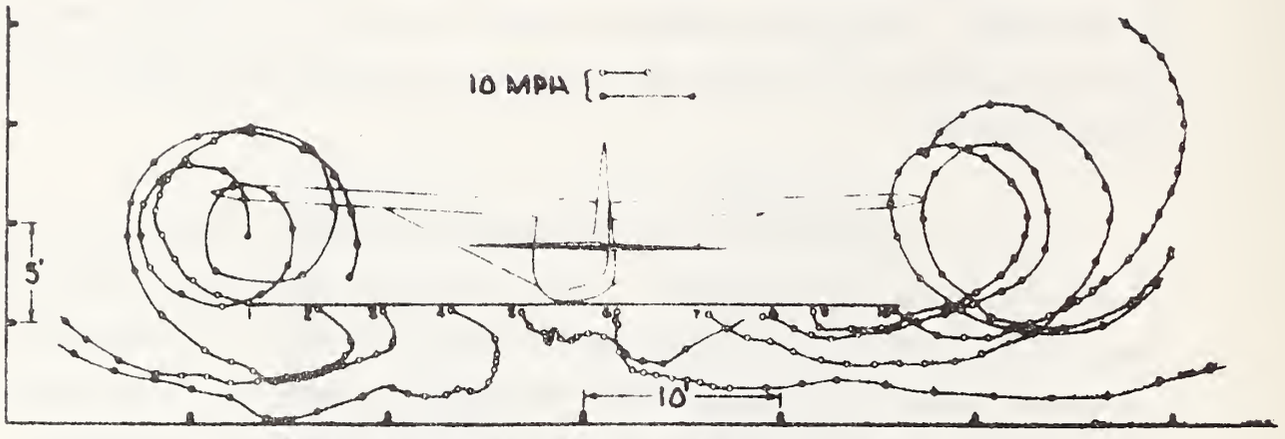
Other work has shown that the spray boom should be located as far below the rotor or wing as possible and the outer orifices should be somewhat inside the rotor or wing tips. Some aerial applicators want to push the spray out as far as possible so they can fly wider swaths, such as with ULV insecticide sprays (400-500 foot swaths) or even sagebrush with 80-100 foot swaths. They should recognize that they may be producing such fine droplets and air conditions that will increase drift and loss of herbicide greatly.

These wing or rotor tip vortices are affected by the attitude of the aircraft. The diagrams shown above were for level flight. If the craft is climbing there will be more down push and less tendency to pull spray up

FIGURE 11

Comparison of Air Currents in Wake of a

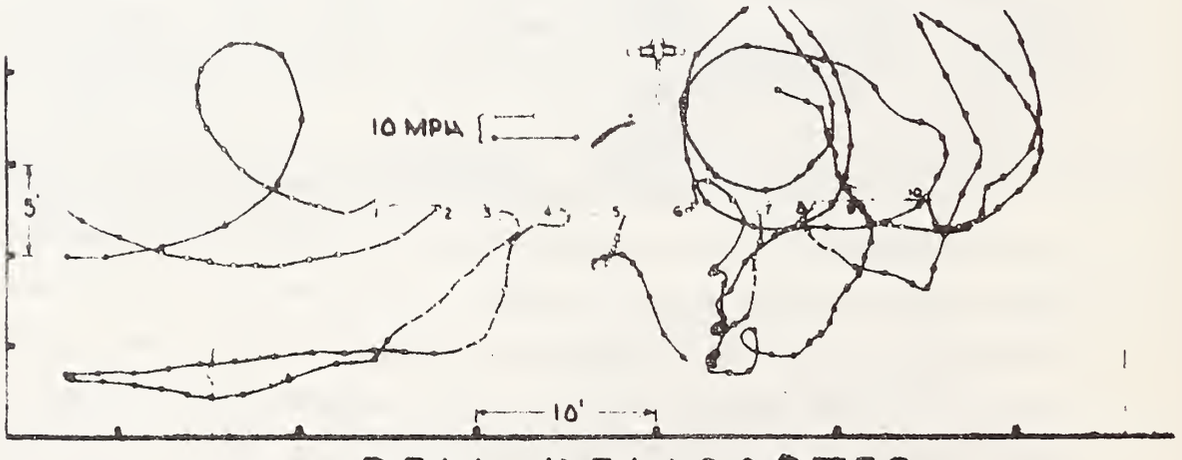
High Wing Monoplane and a Helicopter



FAIRCHILD ~ Model 24

BOOM LOW

80 MPH ~ LOW FLIGHT



BELL HELICOPTER

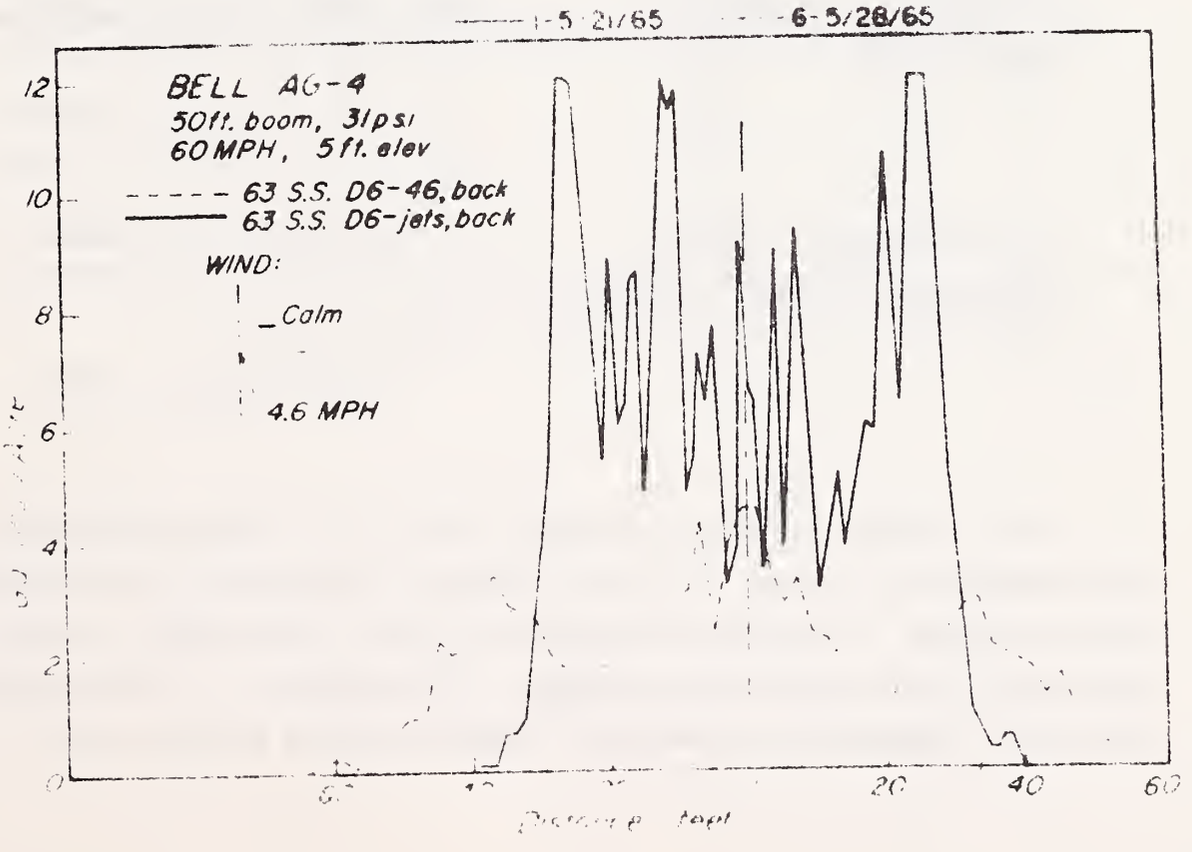
55 MPH ~ HIGH FLIGHT

--From Akesson, Yates & Burgovne,
ASAE Paper #66-104

into the vortices. If the craft is descending, the wing or rotor tip vortices will pull more spray aloft; various portions of the spray pattern will be disturbed more as well. Level or slightly ascending flight is usually best to alleviate both effects.

The influence of swath width is not easily separated from other factors. From previous disucssions, however, it is apparent that wider swath widths with any given spray system will cause more drift, much as wider angle fan sprays cause finer droplet sizes. Tests were run with D6 orifices pointed back on a 50' boom mounted on a Bell AG-4 helicopter. One set had #46 swirl plates and the other had only the orifice. The flow was somewhat greater without the swirl plate but the pattern is indicative of the drift we may expect. The patterns are plotted in Fig. 12. The jets produced a sharp edge to the deposit pattern whereas the D6-46 orifices trailed out considerably. The effective swath width is about the same with both--about 70 feet. The drift will certainly be much greater with the latter system.

FIGURE 12



--from Akesson, Yates & Burgoyne

Effective swath widths are generally about 150% of the boom, wing or rotor widths, except with high vortice effect or deliberate ULV applications.

Tests to determine the effect of number of contiguous swaths shows that there is an increase in drift with more swaths, as presented in Table 8. Under normal unstable air conditions with the system referred to above, but using 1 lb. of DDT per acre and a "fine" spray, the amount of drift at 100' was about 35% more with 80 passes than with 20, whereas it was doubled at 1000' and 3 times as much at 2000 feet. The effect of swath numbers on drift is shown graphically for 1 to 80 swaths (Fig. 13). Just one to three passes, such as on a power line, produces much less drift downwind than the accumulation from 20 to 80 passes, such as would occur in a wheat field.

TABLE 8. Drift from Aerial Application of DDT Related to Number of Swaths and Air Stability

Air Stability	No. of Swaths	PPM DDT on Alfalfa				
		Feet Downwind				
		100	200	400	1000	2000
Normal lapse	80	1.8	0.8	0.5	0.20	0.09
" "	40	1.6	0.7	0.4	0.14	0.05
" "	20	1.4	0.6	0.3	0.10	0.03
2-5° Inversion	80-20	3X above to 10X above				

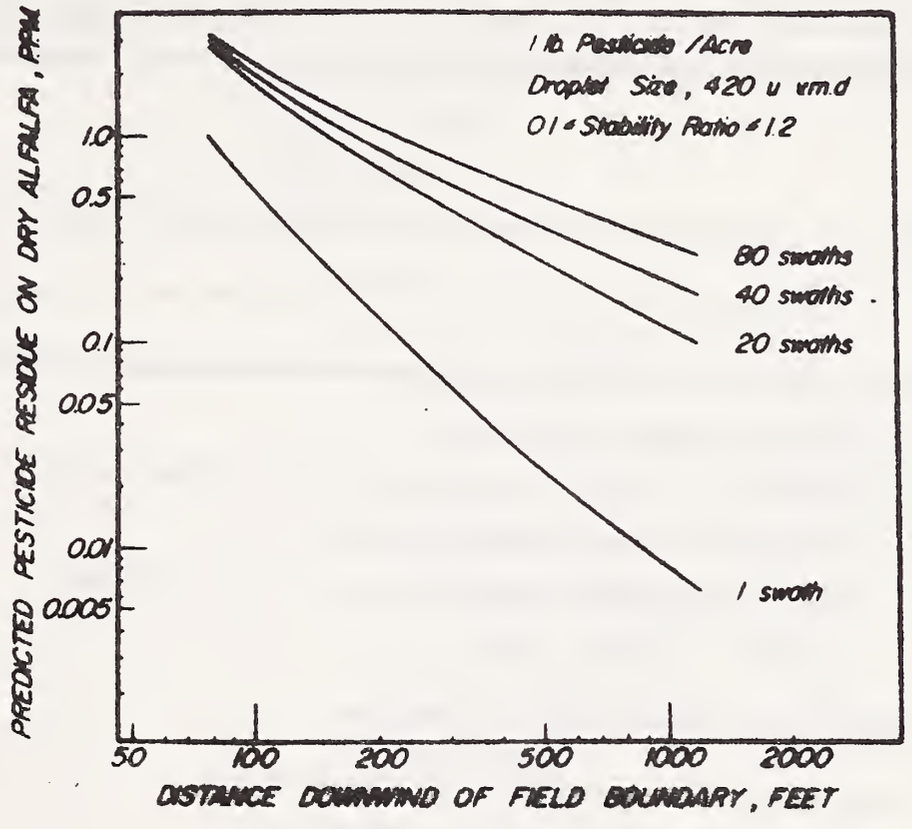
Atomization = Fine (150 μ)
Applied at 1 lb. DDT in 10 gal. spray per acre.

--From Akesson & Yates

The different factors affecting droplet size and consequently drift are summarized in Table 9. These factors do not have equal importance, but attempting to weight each one is difficult since they may have more influence in one system than another. Nevertheless, I have endeavored to place more importance on certain factors, using a rating scale of 1, 2

FIGURE 13

Effect of size of treatment area on drift deposits.



--Yates & Akesson

and 3. It would be possible to make better judgements when the details of a particular system and the objectives of the application are known. Some of these factors are itemized in Fig. 14 indicating the direction of influence each has on drift. Together with the importance of judgement, it should be possible to develop systems and adjust to conditions to minimize drift.

TABLE 9. Factors Affecting Drift of Aerially Applied Herbicides

Factor	Relative Importance
1. Herbicide - Nature and Rate:	
a. Effect on humans, animals, plants, fish, etc.	1
b. Possible water contamination.	2
c. Possible illegal residues on crops or animals.	1
d. Effects on drop size.	2
2. Nature and volume rate of carrier.	1
3. Spray drop size spectrum, as affected by:	
a. Nozzle type, capacity or pressure.	1
b. Nozzle orientation to airstream.	1
c. Boom location cf. wing or rotor.	2
d. Speed of aircraft.	2
e. Viscosity.	2
4. Application conditions:	
a. Flight path - Level, rising, falling or turning.	3
b. Height of release.	2
c. Wind speed and direction.	1
d. Air stability (vertical movement).	2
e. Width of swath.	2
f. Number of passes.	1
5. Distance and direction to problem areas.	1
6. Screening effect of barriers - Trees, etc.	3
7. Turning area and technique.	3

FIGURE 14.

Effect of Various Factors on Herbicide Drift

Less ← Drift → More			
Lower	A.	Release height	Higher
Lower	B.	Wind speed	Higher
Easter	C.	Droplet fall rate	Slower
Larger		1. Droplet Size	Smaller
Lower		a. Pressure	Higher
Jet		b. Nozzle type	
Greater		c. Nozzle capacity	Smaller
Larger		d. Orifice size	Smaller
Round		e. Orifice shape	Sharp angles
Lower		f. Air shear on spray	Higher
Higher		g. Surface tension	Lower
Higher		h. Spray density	Lower
Higher		i. Viscosity	Lower
Down		2. Vertical air motion	Up
Reduced		3. Air stability	Greater
		4. Aircraft turbulence	
Slower		a. Speed	Faster
Climbing		b. Flight direction	Falling
Narrower	D.	Swath width	Wider
Less	E.	Number of contiguous swaths	More

Many of you may want to determine whether patterns of plant injury or other evidence of off-target effects are from drift, volatility or other causes. Drift and volatility usually produce patterns of decreasing effects from the source. With certain carriers, such as oils or invert emulsions, there may be more fines at 50 to 100' in the air several hundred feet downwind than at the surface. This usually results in more drift but may not produce less surface deposit at these points. Also, under inversion conditions, fine particles released above the inversion may distribute erratically as they penetrate the layer. Chemicals, moving as vapor, will follow the horizontal and vertical air movements. Checking wind speed and direction and air temperatures during application and for several weeks thereafter as well as the nature of the herbicide and carriers used will help to analyze the problems. Sometimes low volatile herbicides may cause damage to nearby plants. Continuous exposure of a susceptible plant to vapors of a herbicide for several days or weeks can cause effects that do not seem related. Noting turning areas will help indicate if this is a problem; pilots should choose turning areas carefully. The summary of drift factors, above, and adding the volatility factors could serve as a check list in evaluation of problems.

I hope this presentation will help you understand and place in perspective the important drift and volatility problems in spray applications. A total assessment of hazard will of course include proximity to problem areas, such as water bodies used for domestic or irrigation purposes, susceptible plants, etc., the possible residue problems as well as the application conditions. Applications by air or ground can be made with effectiveness and safety to non-target locations.

Presented at
Montana Herbicide Workshops
October 12-20, 1972

DRIFT CONTROL SYSTEMS

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Davis, California

Herbicides in various forms are applied using several methods and systems by ground or air. As we indicated earlier, aerial applications offer the greatest chance for drift as defined earlier, but a helicopter applying a granular non-dust product will produce much less drift than a ground air carrier (mist blower) applying sprays up to 60' from the rig. A careful aerial application of spray can be much more free from drift than spraying with poorly directed nozzles at high pressure from the back of a truck in a 15-20 mph wind. Changing to proper nozzles and directing the spray can essentially eliminate drift in some situations.

We will try to provide some information now on the possible methods and systems available to reduce drift from sprays to "insignificant" levels. The importance of these levels will be related to the possible effect on adjacent non-target areas, e.g., an application of 2,4-D to a grain field will be of much more concern for an adjacent sugar beet field than for a pasture.

We must usually accept a compromise between the droplets large enough that they will settle to the target readily and having them small enough that they will provide sufficient coverage to achieve the desired control of the vegetation. Herbicides require different degrees of coverage depending on their nature, carrier and surfactants. Contact herbicides and some foliar systemic herbicides require very good coverage whereas some hormone type herbicides can be more sparsely distributed. These generalities will help only slightly until the particular weed or brush control project is defined.

We did, however, indicate in the discussion of drift that we should try to keep average volume drop size above 150 u and that a size range from 150 u to 400 u should give good coverage with low drift.

One of the most important ingredients in controlling drift is the judgement of the spray applicator. If he is knowledgeable and concerned about drift he will ensure setting up adequately with equipment, nozzles, pressure, etc., and will exercise good judgement in proximity of the spray to problem areas. We cannot emphasize this feature of the job too much.

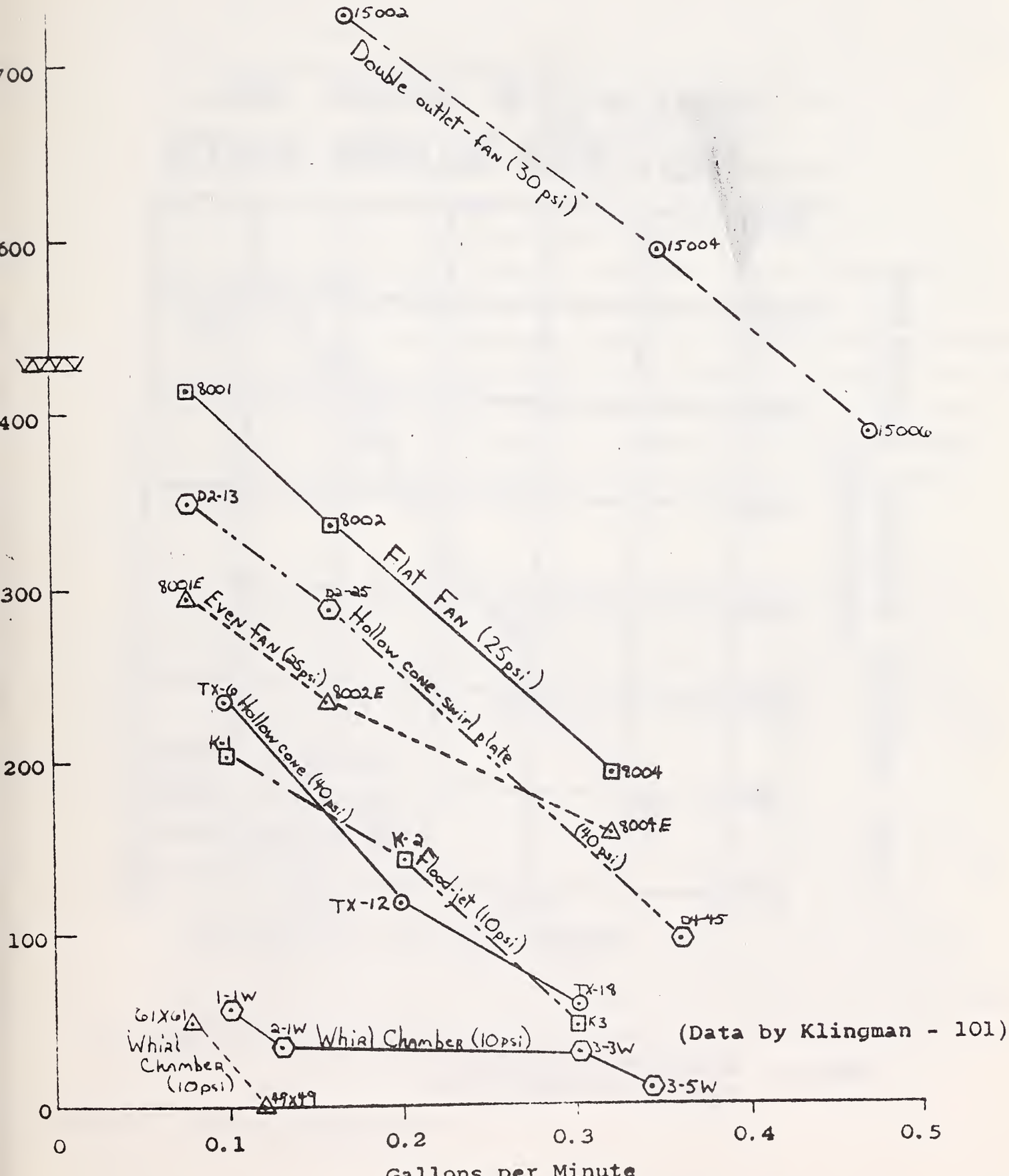
Several features of sprayer systems can be altered to provide good drift reduction without changing the spray mix. You may recall from the discussion of drift, these include nozzle type, pressure, angle of nozzle to air movement, or angle of projection and location of the boom or nozzles. Nozzle type includes the shape and size of orifice and the deflection or directing forces inside the nozzle.

Herbicides are applied with a large variety of nozzles to produce certain patterns or break-up and application convenience. Drop size is affected greatly. Basically there are flat fan, cone, jet and off-center nozzles in common use. Within these groups there are normal fans with tapered edges in agles from 5 to 150°, deflector types in 15° to 150° fans, even-fan type (sharp end) fans, hollow cones from whirljets or D-orifices with swirl plates, solid cones with D-series, TG tips or GG nozzles in angles from 15 to 120° cones, and jets produced by D-orifices or the tapered V-jet 0° jet types. The agricultural and industiral nozzle catalogues provided by Spraying Systems Co., Delavan Mfg. Co., and others should be consulted for details of these various types. Much more information is available on request.

Klingman compared several types in a study to evaluate spray drift at similar flow rates. Fig. 1 shows the nozzle types used and results. The even-fan nozzle produced less drift than the normal fan type. The hollow cone D-series at 40 psi produced less drift than the flat fan at 25 pis. The floodjet at 10 psi gave less drift than either and the whirljet had the least drift. Tate reports that Delavan cone, flat or flooding type nozzles produce about the same drop size spectrum as shown in Fig. 2. The effect of flow rate is shown also; drop size varies directly with flow rate at a given pressure.

FIGURE 1

Drift from Different Types of Nozzles



Note 1. The first 2 or 3 digits of flat-fan numbers indicate fan angle.

Note 2. The double outlet curve has been displaced downward 100 psi.

--Adapted from data by Klingman.

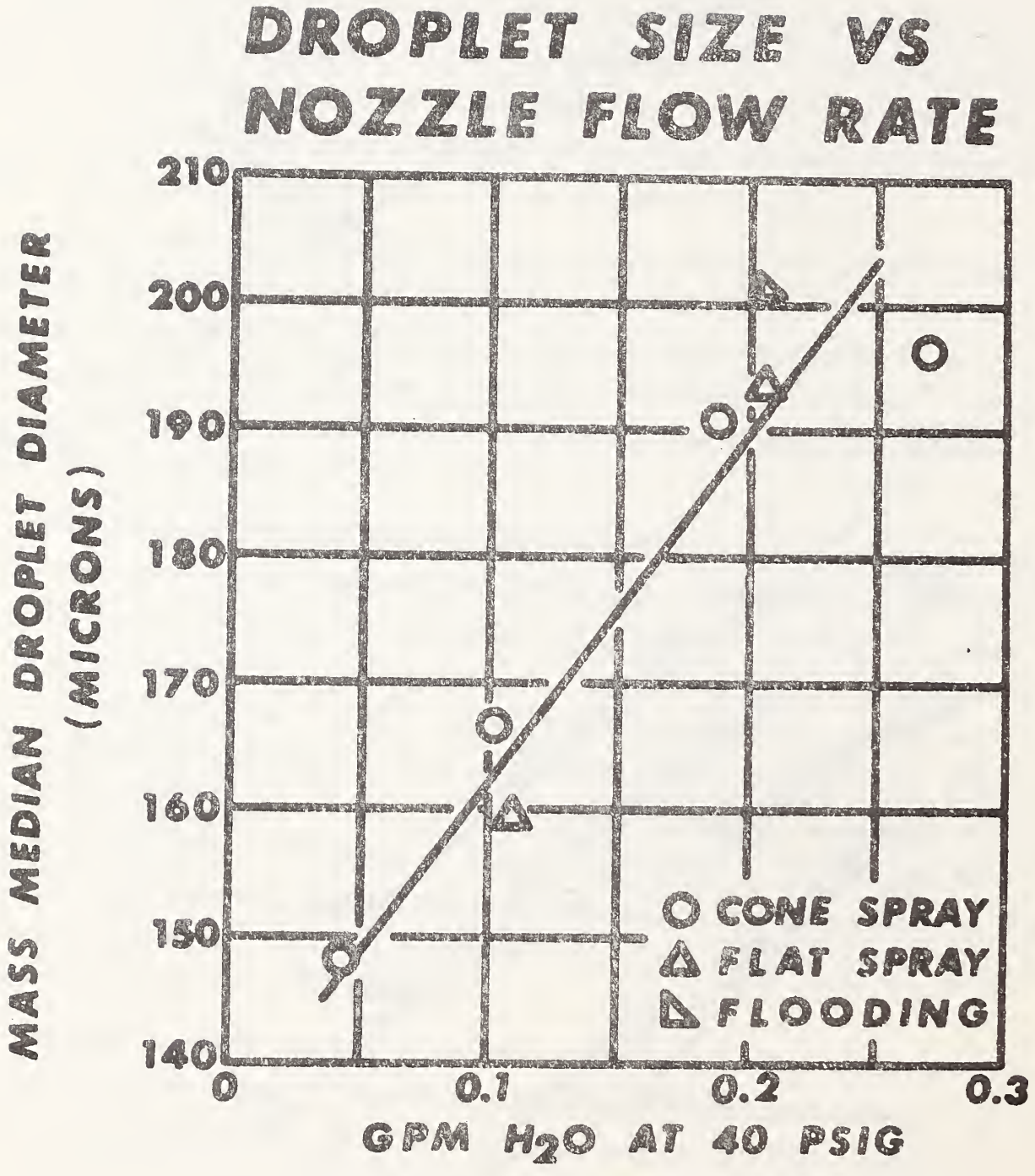


Figure 2. Droplet Size Increased With Capacity But Was Relatively Insensitive to Nozzle Type.

--From Tate and Janssen, Proceedings, ASAE, 1965

The fulljet type with built in swirl device produces much less fines than the D-series with the swirl plate, the flat fan, whirljet or deflector types at equivalent pressures. The D-orifice without the swirl plate gives a straight stream, but the V-jet 0° produces the least amount of drift (fines 150 u). The V-jet has a long taper approach to a round orifice. The U-jet 0° tip is a round orifice with a short taper between the V-jet long taper and the flat plate, such as the D-series without a core. The break-up with these tips is much more than with the V-jet, but is still much less than with fans or cones. Using the U-jet or D plate without the core may be an easy way to increase coverage and still contain the drift. Inspection of drop size distribution curves for many different nozzle types indicates that there is little variation in range of drop sizes, even though the volume mean diameter will change considerably. Some nozzles, such as the whirljet or deflector types, allow production of a suitable pattern at lower pressure than for flat fan or cone nozzles, which will reduce fines.

The core in the D-series has only the angled slots for the hollow cone and merely adds a hole in the center to produce a "full" cone. The deflector vanes in the TG and GG types accomplish more uniform spray break-up with a full cone for a given output and pressure; the droplet size range is the same, but average size with full cones is greater than with the D-series.

The off-center tip will project a spray to the side 5 to 20 feet. It has a narrow V at the near end of the orifice which produces very fine droplets and the rounded outer end is similar to a jet in break-up. It is quite useful, however, for certain applications by ground equipment until wear distorts the orifice shape. Oil carriers will be broken up too much by this nozzle; in tests, several jet or narrow full cone nozzles were found to give coverage without excessive drift of oil carriers.

Deflector nozzles produce a fan spray in a wide range of angles by projecting a jet against an angled deflector outside the orifice. They are used for some crop applications because a good pattern is produced at pressures of 10 to 20 psi. They are not suitable for thickened sprays because the spray tends to drip from the edges.

The break-up of spray as it hits the air for a given nozzle and pressure will be the same for ground or aerial application. The effect of air shear, mentioned in the previous article, is the result of air speed and spray projection cf. sprayer movement. At the speeds used for ground applicators, these factors will be less important than for aerial applications.

Considerably finer spray from aircraft is produced when the nozzles are faced into the wind vs. with the wind (45° to front vs. 45° to back). As the speed of the aircraft increases from 25 to 50 or 100 mph, droplet sizes decrease, vortices enlarge and potential drift is increased. Higher pressure increases the number of fine particles, but in the range from 15 to 40 psi, is less important than some of the other factors. On a helicopter or plane, the least drift will be sustained using V-jet nozzles at low pressure using the largest size possible consistent with obtaining adequate coverage, pointed back and down 10°, flying as slowly as possible in a level or slightly rising path, about 10 feet above the target, with no or slight wind and no inversion. Most of these factors can be adjusted for a particular application to accomodate available equipment or achieve better coverage.

Since ground applications can produce drift, these same analyses and suggestions apply although the relative importance may be less. The air carrier (mist blower) units and high pressure guns are most likely to cause problems and need the extra care and alterations. Check valves on all nozzles and "suck back" systems on aircraft to prevent drip are needed. Also the pressure should be gauged at or very near the nozzles.

Two other practical mechanical systems have been developed to reduce drift. For ground application, Amchem's Directa-Spray is an electrically driven whirling device that throws the spray out over 25' to a side through an arc that can be varied. The volume rate is metered to the whirling head through 6 orifices. This device appears to give good reduction in drift and good coverage of vegetation if properly directed.

Amchem also developed the Microfoil boom, an aerial drift reduction system for helicopters at speeds less than 60 mph. Drift control is accomplished by dispensing the spray through a large number of small hypodermic needle type tubes--3200 per 26 feet of boom. The tubes are located on the trailing edge of the airfoil boom and proper flying attitude allows collection of these fine droplets in larger drops. This method of producing drops minimizes the number of small droplets. A narrow range of drop sizes in the final spray results, but the size is too large (800-1200 u) for good coverage at low volume rates, such as 3 to 5 gpa for sagebrush work. The flow rate of the liquid through the small tubes is also affected by viscosity changes. Carriers such as diesel oil that increase their viscosity with lower temperature may seriously affect volume rates through the Microfoil.

Further efforts to reduce drift without thickening the spray include the carrier and volume rate. Experiments have shown that oil or additives that reduce surface tension increases the fine particles that can drift. Drift will be less as the oil fraction in a spray is decreased. Anyone who has used straight oil carrier has seen the mist cloud at the nozzle.

Certain spray applications require either an oil carrier or a certain mixture with oil. The operator will then need to adjust other parts of the system.

Increasing volume rate has been suggested as a way to reduce drift. I indicated earlier that higher flow rate would increase drop size. Drift will be reduced by increasing volume rate only if the nozzles are enlarged to accommodate the higher output rather than adding more nozzles or increasing pressure. Volume rate can be increased by increasing pressure, reducing the spray speed, adding more nozzles, or making 2 or more passes without changing nozzles. With these last changes, drift is likely to be increased with higher volume rates. From one standpoint the hazard from drift of herbicides at higher volume rates will be less because a given amount of drift will have less active ingredient. Trying to evaluate drift at volume rates from 5 to 20 gpa by air involves so many other factors that the effect of volume rate is insignificant from a drift standpoint; but it may be quite important in obtaining adequate coverage. Again, other adjustments should then be made in the systems to reduce drift.

VISCOSITY MODIFIERS

Increasing the viscosity of a spray generally will increase the average drop size. Various agents will simply increase the viscosity of water or oil carrier, will impart a particulate form or thixotropic nature or produce a two phase mix of oil and water with emulsifier called an invert emulsion. Any number of materials will thicken water; the agent must be compatible with the herbicide and allow relative ease of mixing. Products that are marketed for this purpose include Vistik (hydroxyethyl cellulose), Endrift (Nalco), and some others. These products do decrease fines and consequently drift if mixed properly and sprayed through the proper nozzles. They must be thoroughly mixed for several minutes after addition to the water to prevent gelling. They should be pumped with positive displacement pumps (piston, gear, sliding vane, etc.) to maintain a reliable output. The pipes and/or hoses to the nozzle should be large enough to carry the thicker liquid without losing pressure too much. The pressure gauge should be located very close to the nozzles for accuracy.

Another type of viscosity modifier is a particulating agent. NORBAK® is the only such product known at present. It is a water swellable polymer that absorbs water but does not dissolve; it is screened to have a final particle size of 250 to 500 μ. After it hydrates in 10 to 20 minutes it maintains its beady nature during the application, and as long as the water does not evaporate. It is probably the most effective drift control agent for water soluble herbicides. Mixing and application must be done carefully. NORBAK has been used only to control drift with TORDON® 101 Mixture (picloram + 2,4-D) on rights-of-way and is not generally available.

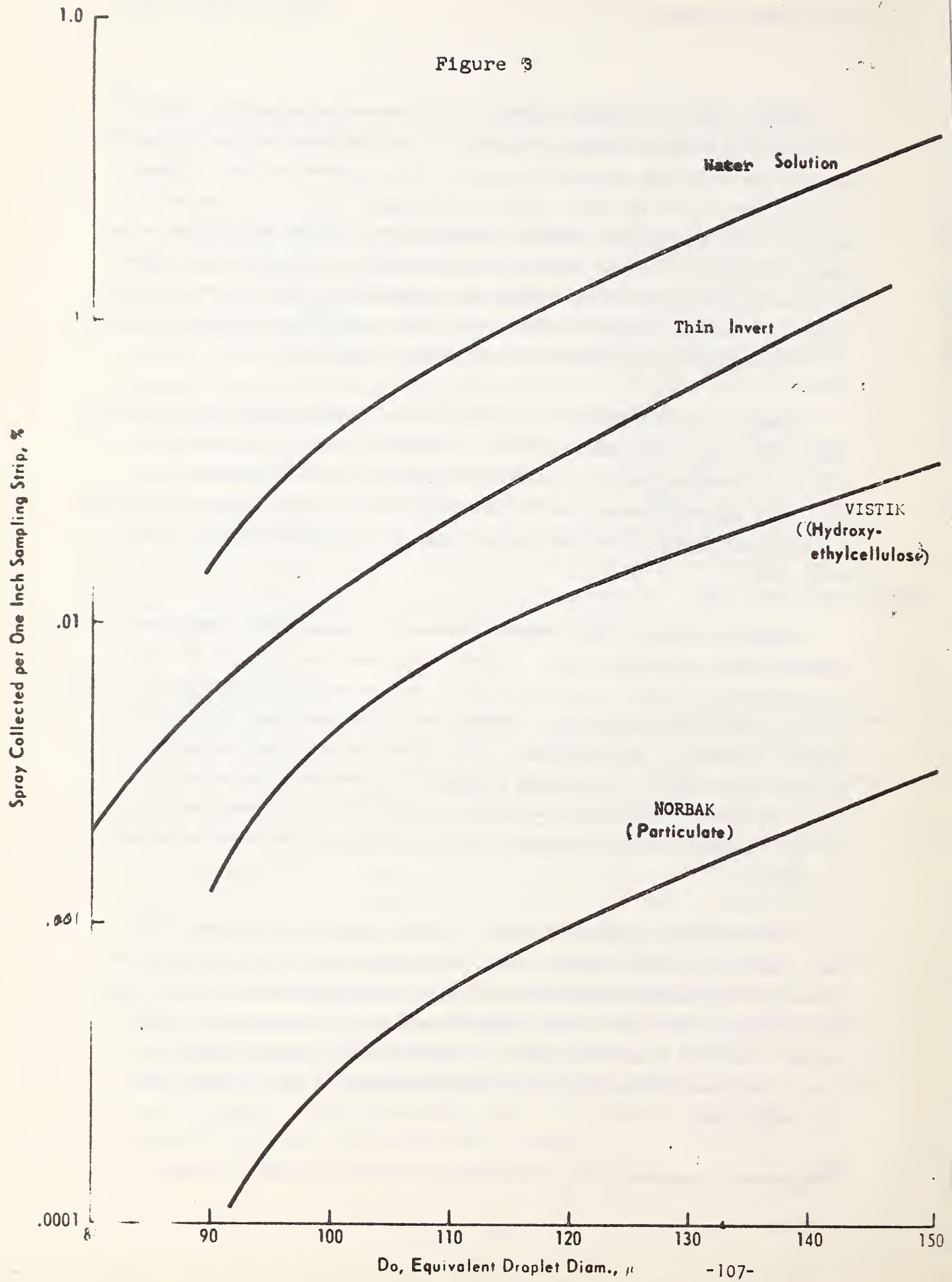
Dacagin is a pseudoplastic thixotropic wax product that works differently than plain thickening agents. When it is added to water, it thickens the spray, but when subjected to pressure or shear, such as by the pump, it thins down during movement and thickens again as the spray leaves the nozzles. In controlled tests, it has been about equal to Vistik in reducing drift of herbicides.

Recently there has been renewed interest in using invert emulsions to thicken sprays and reduce drift. Invert emulsions form when an oil phase in a water-oil mixture becomes continuous and the water is dispersed in cells; it has a milky-thick appearance. Normal emulsions have the oil dispersed, usually by means of an emulsifier, in the water phase. When the spray of an invert emulsion is formed from a nozzle, the droplets have an oil film which can prevent evaporation while falling; droplets of normal emulsions can and do evaporate while falling in the air because the water is exposed to the air.

The drift from spray with Vistik, a thin invert emulsion and NORBAK were compared in wind tunnel studies. The results are shown in Fig. 3 as lines showing the size and amount of spray collected downwind. There was little difference in drop size range between any of these agents or with water. The thin invert had about 40% as much drift as water carrier; Vistik had about 10% as much, and NORBAK had about 1% of the drift from the water spray.

®Registered trademark of The Dow Chemical Company, Midland, Michigan.

Figure 3


1.0
1
.01
.001
.0001
Water Solution
Thin Invert
VISTIK
((Hydroxy-
ethylcellulose)
NORBAK
(Particulate)
Spray Collected per One Inch Sampling Strip, %
80
90
100
110
120
130
140
150
Do, Equivalent Droplet Diam., μ

Invert emulsions offer considerable flexibility in adjusting viscosity if the proper equipment and techniques are used. It is possible to either mix the ingredients in the tank before spraying or to mix them in the line or pump as they are being sprayed. This is called a bi-fluid system; it has an advantage in not making the final spray mix until it is being applied. The equipment and techniques for accurate application rates require more care and precision than the tank mix procedure, but the advantages could justify this approach.

Invert emulsions are prepared by adding the water phase to the oil phase with good agitation or high shear. The herbicide would have been mixed previously into either the oil or water or both. The inverting agent may be a separate product or in the herbicide; it is added to the oil before adding the water. When the oil and water phases are mixed with sufficient agitation, the water is dispersed and the liquid becomes an invert emulsion, but may not be thick enough to reduce drift adequately. Some added shear in the form of agitation will divide the water cells more and induce thickening, which can continue until the oil is no longer sufficient to spread around the water cells; then the emulsion will break or clabber. As more oil is added to the mix, the viscosity will decrease or become thinner. Viscosity of invert emulsions will be increased by using more or a different inverting agent, decreasing the oil and by increased shear (agitation). Enough agitation may compensate for deficiencies in the other two factors. Oil-to-water phase ratios are usually in the range of 1 part oil to 2 parts water, to as high as 1:15.

Newer inverting agents have been developed that permit reliable use of flash mixing (bi-fluid) systems. The design of the system is important. It must meter the two phases accurately, induce the inversion process, produce the required amount of shear to thicken the invert mix, and apply the herbicide as intended. The systems available now use orifice metering into a mixing chamber just ahead of the pump. The spray mix will be held back enough to recycle either within or around the pump about 1/3 of the volume going out the nozzle. This system requires a positive displacement pump with adequate capacity for at least 50% more than needed for the intended

spray jobs. Certain closed impellor centrifugal, roller or other pumps that will produce pressures over 60 psi have been used successfully to produce lower viscosity invert emulsions, but the thicker mixes usually require the positive displacement pump.

The practical use of invert emulsions include application by ground or air of oil or water soluble herbicides. The oil soluble formulations of herbicides, like 2,4-D or 2,4,5-T, can be either low volatile esters or oil soluble amines and may be dispersed in the oil or water with adequate emulsifiers; however, in the water phase some agitation is usually required. Water soluble herbicides, such as amine salts of 2,4-D or picloram, of course must be in the water phase.

As indicated above, some systems have been set up to draw the chemical into the line before the mixing chamber directly from tanks or the product container. With a correct metering device, this is quite satisfactory. In all the systems involving suction of herbicides through orifices for metering, extreme care is needed to prevent any air leaks.

Only a few products are available that are invert emulsion formulations of 2,4-D or 2,4,5-T. Hercules (now Rhodia-Chipman) has ViskoRhap; Dow has VERTON^{R} products and Amchem has Envert.^{R} For ground application, Hercules developed flash mixing equipment that is quite satisfactory; this is called the Wanner sprayer now. It has orifice metering of both water and oil, a higher pressure pump and an "invertor" that is really only a thickening device. The thickened spray is immediately applied through jet nozzles oriented to obtain good coverage. Dow has two new VERTON products--2,4-D and 2,4,5-T--that can be flash mixed similarly and even in less complicated equipment; it can also be tank mixed if desired. For right-of-way spraying by ground or air, where drift is an ever present hazard, viscosities of over 100,000 cp (nearly mayonnaise) are needed along with jet or narrow full cone nozzles to make essentially "drift free" applications. Envert is usable only as a tank mix, but was applied through an 8 nozzle spinner that produced large drops.

At least one product is available that can be added to herbicide sprays to produce invert emulsions. It is called Bivert pH and is diluted about 1:9 in oil for later mixing with the herbicide in water; or the herbicide can be part of the 1 part of oil. This product has been used successfully by air on thousands of acres of sagebrush spraying in the Intermountain area. It is flash mixed on helicopters equipped with a Simplex flash mixing system. Simplex Manufacturing Co. has two flash mixing systems; one uses a closed impellor centrifugal pump (with Bivert sprays) and the other has a Sorenson 1¼" gear pump. They are both quite satisfactory.

Devices to determine the viscosity of thickened sprays may be needed. The Sears paint cup is used for Vistik. Systems using flow rate through a small hole or settling piston have been used for invert emulsions.

Drift hazard in various situations varies greatly. In many range or forestry applications, little drift control as such is needed. However, relief from evaporation of the carrier while falling would be important. This may be a good reason to use invert emulsions, but they need be only moderately thickened, especially since leaf coverage would be important. Because of the flexibility of the system, where more drift control is needed, the oil-water ratio or agitation could be increased or more inverting agent added for a few loads. Care is needed to use the proper nozzles and techniques to take advantage of the viscosity. Thickening sprays only may give a false sense of security.

Herbicides are sometimes applied in oil carrier. 2,4-D esters are used in 2-3 gals. oil per acre to control sagebrush. 2,4,5-T is applied in 10-20 gals. diesel oil per acre over some conifers during dormancy to kill brush. Dormant roadside or right-of-way applications of 2,4,5-T esters, TORDON 155, or Banvel O.S. in oil at 50-100 gpa from a moving vehicle are increasing. Oil breaks up much more readily than does water and drift from these applications could be of concern. Tests with various nozzles included narrow flat fan, deflector fan, solid cones and different jet nozzles. With oil, it was found that the narrow (15-60°) full cone and

jets gave the best drift reduction. A thickening agent for oil has recently been introduced by Amchem and it may be quite satisfactory for both aerial and ground use. Early attempts to thicken oil carriers indicated the acceptable thickening agents would reduce activity of the herbicide.

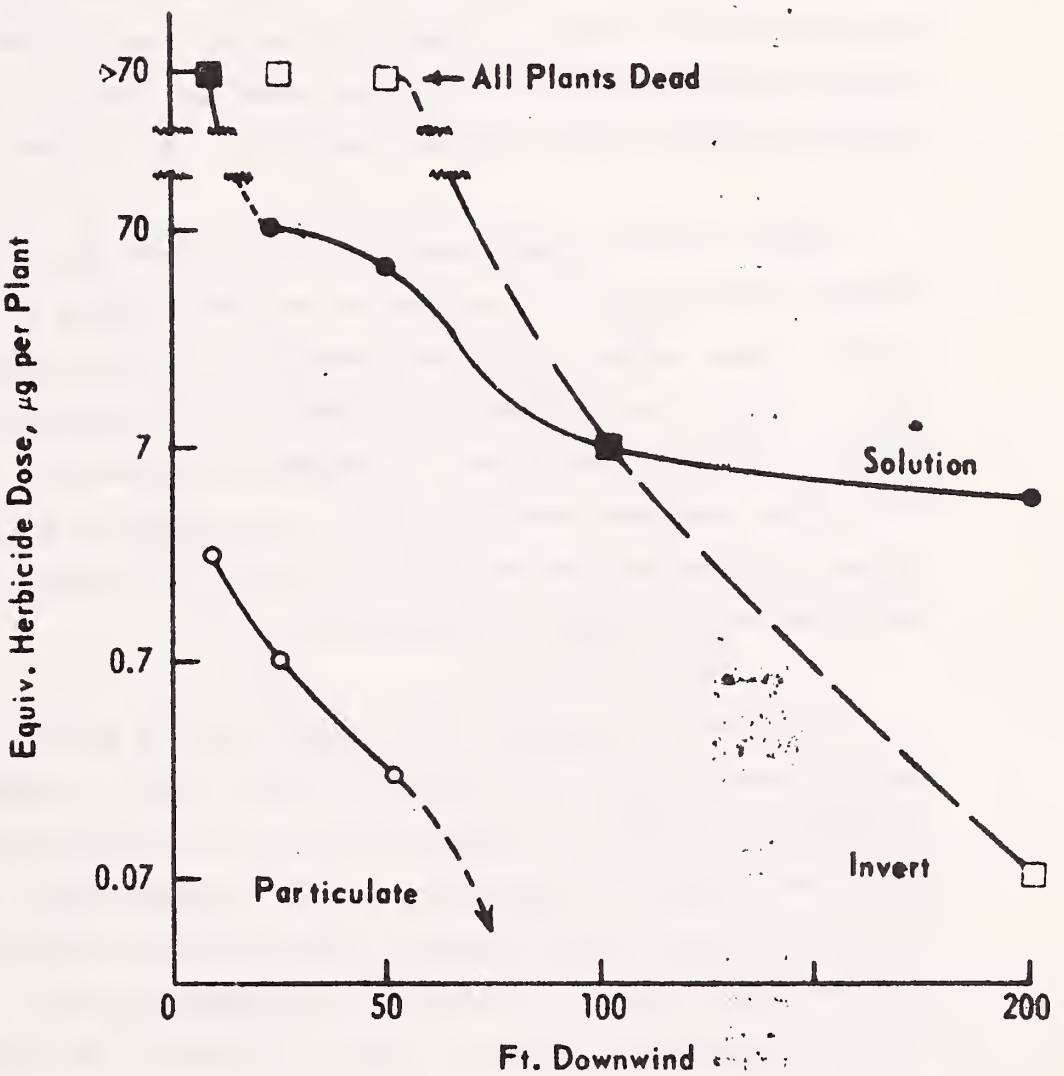
One other system that has been introduced recently involves the use of certain "foaming" agents in the spray along with particular nozzles that entrain air and produce expanded droplets of "heavy" foam. The principle is to expand the spray volume 4 to 7 times and increase the proportion of liquid that is in the larger drop size. Aerial and ground applications are used. Some tests indicate that reduction in drift up to about 60% has been obtained; that 40% that gets away can cause excessive damage, however. In certain situations, such as ground or low level aerial applications in low hazard areas, this system may be satisfactory for targetting. However, for critical drift control it is not adequate. Another aspect of this adjuvant is the possible change in specificity of the herbicide to the crop by the foaming agent. It is a good surfactant and may even have penetrant qualities, so tests of safety should be run on each crop before general use.

Mixing foam sprays is relatively simple; the agent is added to the water with the herbicide as the tank is being filled to a concentration of ½% to 1% of the final spray; oil soluble products require more agent. Usually no changes are needed in the pumping system if it will produce over 40 psi, but special foam nozzles must be used. Extensive research is in progress to determine the utility and safety of this system.

Comparisons of the drift control with different systems using a plant bioassay is helpful in determining the most suitable one. Susceptible plants are located downwind for 500 to 200 ft. on the ground and in the air. Byrd and Seymour in Dow (Fig. 4) found that about 3% as much drift was sustained with inverts as with water, but the particulate was much better. Note that the drift with either additive decreased much more rapidly than with water alone. Results of ground tests using a bean bioassay with TORDON 101 with different drift control agents in Michigan at wind speeds of 4 to 6 mph

FIG. 4

Bioassay of herbicide drift from field tests, ground level results.



From Byrd & Seymour
Proc. A.S.A.E. Dec. 1964

are shown in Fig. 5 by Holmsen et al. Dacagin and Vistik gave similar drift reductions, but were much less effective than NORBAK. Aerial applications of TORDON 101 on beans in California were run using beans as a bioassay. Plants were placed downwind 50' to 500'. All the plants at 500' died with water carrier. Dacagin and Vistik provided about equal drift reduction but allowed serious damage. NORBAK was far superior; essentially no damage at 500' was observed. In addition a thick invert emulsion was found to give nearly as good drift reduction as NORBAK at wind speeds of 6-11 mph. Later tests, using a similar system, in Michigan showed that the invert emulsions should be quite thick to equal the results with NORBAK. Also, with the invert emulsions jet nozzles were found to give much less break up than the large off-center type used successfully with TORDON 101-NORBAK applications.

There has been some work with air carrier sprayers in attempts to reduce drift which is sometimes excessive because of the low volume rates, the air shear effect, and the direction of projection. Thickening agents, such as Vistik and NORBAK, have been used successfully with both the large machines having a positive displacement pump and the small backpack type. The latter required modification to pressurize the spray tank since the normal suction was not reliable to meter thickened mixes. Thin invert emulsions should also be satisfactory.

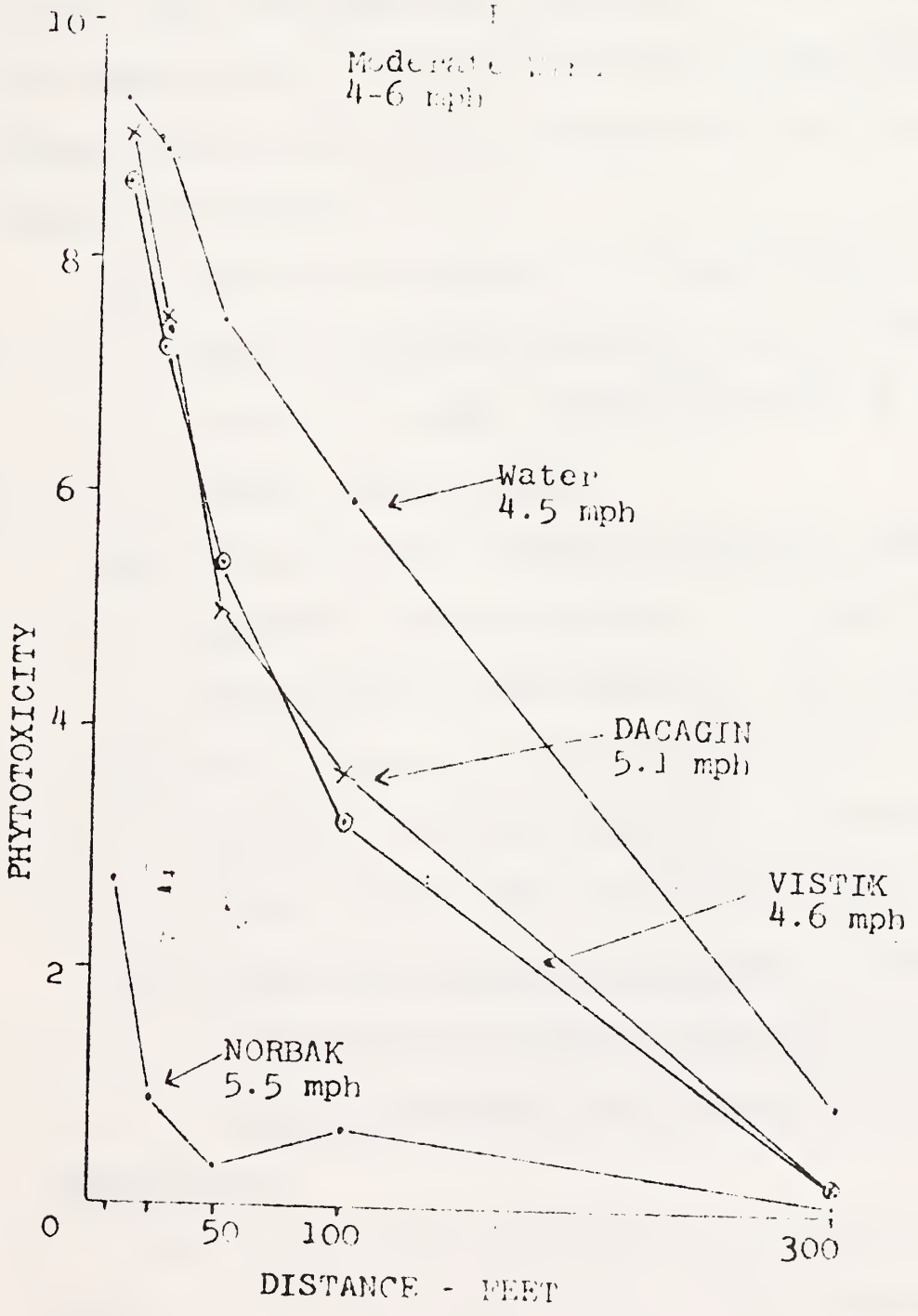
Sometimes an operator will want to use a drift control system that has not been tested. Since drift often cannot be seen, its effect may appear much farther on sensitive plants than realized. It is feasible with some preparation and care to run bioassay drift tests if properly set up to evaluate the hazard to be expected before application or to have a system approved. We will be glad to supply details on the technique to conduct these simple tests. Care in handling the exposed plants is most critical.

In setting up spray rigs for drift reduction, attention should be given to the spray pump and system and the degree of drift control needed. This will indicate which kind of a system will be selected. It may be

FIGURE 5

Drift of TORDON 101 with Different Agents

as indicated by bioassay



---From Holmsen et al.
Proc. N.E. Weed Cont. Conf., 1967

better to build or obtain a complete new sprayer with the desired features. Sprayers can be constructed to handle thickened sprays as well as conventional sprays. For anyone interested, suggestions for sprayers to apply high viscosity sprays or bi-fluid invert emulsion systems can be supplied by The Dow Chemical Company representatives.

MONTANA HIGHWAY DEPARTMENT HERBICIDE APPLICATION SPECIFICATION

I. B. Jensen, Ph.D.

I. EQUIPMENT

At the beginning of the season, thoroughly inspect repair, and calibrate all equipment to be used for herbicide application. It is important to use equipment designed for the job. It is essential that the correct dosage be applied.

(a) Calibrate equipment at least once a year, and when a herbicide mixture with a different viscosity is used. Always operate at the calibrated speed and pressure.

(b) Replace worn nozzles, defective hose, or broken pressure gauge promptly. If leaks develop in the system, stop operation and repair immediately.

(c) It is important that equipment be equipped with positive shutoff controls to prevent dribble from nozzles when herbicide is not being applied.

(d) Never use excessive pressure. Remember that increasing the pressure decreases the droplet size hence increasing the possibility of excess drift.

II. APPLICATION

The key to safe and effective application of herbicides is to follow directions on the container label and not to use any herbicide preparation for any purpose for

which it is not specified. Care and precision in the procedures used in applying agricultural chemicals greatly affects the overall success of the treatment and prevents contamination of adjacent areas. Effectiveness of a given treatment may also be greatly influenced by such factors as the growth stage of the weeds to be controlled, weather conditions, type and formulation of herbicide, dosage of herbicide and application equipment used.

(a) Ester formulations of hormone type herbicides shall not be used.

(b) When air temperature exceeds 85° F. hormone type herbicides shall not be applied.

(c) Every sprayer operator shall be able to identify all noxious weeds.

(d) Tall non-noxious weeds such as Sweet Clover, Fire Weed, etc., shall not be sprayed after they are over two and one half feet tall unless written consent is given to do otherwise.

(e) Trees and shrubs taller than two and one half feet shall not be sprayed unless written consent is given to do otherwise.

(f) Hormone type herbicides shall be applied to noxious weeds prior to their full bloom stage or during the late summer if maximum efficiency and kill can be expected.

(g) At least three days prior to starting to spray a roadside, the Montana Highway Commission Maintenance Section shall be notified.

(h) Do not apply herbicides near or into irrigation ditches or contaminate water subsequently used for irrigation. Do not spray near any water used for drinking or other domestic purposes.

(i) The application of liquid or powder herbicides shall cease when wind velocity exceeds ten M.P.H. unless the nature of the terrain or equipment is such as to eliminate the possibility of excessive drift.

(j) Avoid spraying along streambanks or other areas heavily vegetated with shrubs and desirable broad leaf plants if there is any chance of herbicide drift.

(k) Liquid herbicide application equipment shall not be operated at a pressure in excess of sixty pounds of pressure per square inch, unless written consent is granted to do otherwise.

(l) When applying liquid hormone type herbicides at least thirty gallons of water per acre shall be used in the mixture.

(m) When applying water soluble or wettable powder type soil sterilants at least fifty gallons of

water per acre shall be used in the mixture.

III. EQUIPMENT OPERATORS

A minimum of one qualified and experienced herbicide equipment operator must be with each spray vehicle when operating on Montana Highway Right-of-Way.

IV. SAFETY

The equipment operators shall be responsible to install and maintain safety devices and protective equipment reasonably necessary to protect the life and health of employees on the job and the safety of the public.

V. DISPOSAL OF HERBICIDE CONTAINER, EXCESS HERBICIDE MIXTURE AND CLEANING OF EQUIPMENT

The careful cleaning of equipment, disposal of empty herbicide containers and surplus herbicides is an important part of safe herbicide use. Persons using herbicides must follow safe disposal procedures because their errors could lead to serious hazards to themselves and others and serious contamination of the environment.

(a) Empty herbicide containers shall be disposed of at a sanitary land fill type dump or other suitable area. They shall not be abandoned.

(b) Do not dispose of excess herbicide near irrigation or drainage ditches. Pour excess herbicides into a hole dug in level ground in an isolated area where they will not contaminate water supplies and cover with dirt to a depth of at least eighteen

inches. A sanitary land-fill can also be used.

(c) Do not wash any spray equipment or herbicide containers in any lake, pond, river, stream, or any other area where the presence of a herbicide may be harmful.

VI. RECORD KEEPING

Persons applying herbicides must keep a record of the area treated. Such information is a great value for evaluating the chemicals and the total effectiveness of the herbicide program. It also serves as a safeguard for the applicator and the property owner.

VII. BILLING

The State Highway Commission Maintenance Department must be sent a bill along with a Herbicide Application Record within thirty days after herbicide application.

HERBICIDE APPLICATION EQUIPMENT

by

M. J. Jackson
Extension Agronomist

The use of pesticides is becoming more complex every year. It is important that the right pesticide is applied at the right time and proper rate, so as not to contaminate the environment. One of the most important aspects of pesticide usage is using the correct application equipment.

The application of herbicides is no different than any other pesticide. Its effectiveness depends upon the use of the proper herbicide formulation, applied at the correct rate, with suitable application equipment which is properly adjusted and operated Accurate calibration of the equipment is important. A variation in the rate of application may cause failure to control the weed, or injury to the crop.

There is a variety of application equipment on the market. The kind used will depend upon the product being treated and the formulation of the herbicide being used. Application equipment is available for liquid and granular formulations and dusts. Either power-driven or hand-operated equipment can be purchased.

Equipment used to apply herbicides in Montana usually is of the power-driven liquid or granular applicator class. Power sprayers of the hydraulic type can be purchased as small general-use sprayers; multiple-purpose farm sprayers; high-pressure, high-volume sprayers; low-pressure, low-volume sprayers; and self-propelled, high-clearance sprayers. The low-pressure, low-volume sprayers which produce less than 100 pounds pressure and three to 50 gallons per acre application generally are used for weed control.

Pump

The pump (along with other components) determines the spray pressure and capacity of the sprayer, and the kinds of spray materials which can be handled The type and size of the pump needed depends upon the spray job. Some jobs are best done with low-pressure and high-volume spraying. Others require high-pressure and low-volume. Still others can be done with low pressure and low volume. The size of the job and the number of acres to be treated are important factors.

As you know, spray recommendations vary with the species of weeds treated, and may even vary within the species. The pump should be large enough to apply the optimum volume of spray needed at adequate pressure for uniform coverage. Recommendations for weed control in most crops require volumes up to 20 gallons per acre at comparatively low spraying pressures. For applying sprays to control weeds in non-crop areas, the pump size should be large enough to apply a volume up to 100 gallons per acre. The volume needed will depend upon the amount of foliage to cover for optimum control.

Tank

Tanks used in applying chemical sprays usually are made of metal or fiberglass. Metal tanks should be coated on the inside with a chemical-resistant material to prevent rusting and scaling. The inside corners should be rounded to facilitate the cleaning out of chemical residues.

Sprayer tanks should have a large, covered opening in the top, fitted with a removable strainer for ease of filling, inspection and cleaning. A drain plug should be provided in the bottom to permit complete drainage when cleaning.

The capacity of the tank will depend largely upon the capacity of the pump used and the availability of water for mixing. Commercially available units are generally 10 to 20 times the per minute capacity of the pump. For example, a 20 gallon per minute pump normally will have a 200 to 400 gallon

tank. For a spray program where different volumes of spray are needed, two spray tanks should be used. For instance, if spraying an area with a boom applying a volume of 20 gallons per acre, and another area with a handgun requiring a greater volume (100 gallons per acre), it is impossible to mix the right amount of chemical for both areas. Different tanks or different sprayers should be used if the same chemical rate per acre is applied with different volumes of carrier.

Agitation

The agitation of spray material in the tank is important to getting uniform mixture and application of the chemical. Two methods of agitation used are mechanical and hydraulic. With mechanical agitation, paddles or propellers are placed in the tank and rotated while the sprayer is in operation. Hydraulic agitation is provided by the overflow action from the by-pass line to the tank, and by placing an agitator line with a jet device near the bottom. Continuous, positive agitation is necessary to be able to use the full range of spray materials such as wettable powders, oil and water emulsions and others. Mechanical agitation is considered better than hydraulic agitation. However, excessive agitation of certain solutions and emulsions may cause foaming, heating or other undesirable results.

Nozzles

The nozzles used for a boom, handgun or broad-jet type application determine the angle of spray, the type of spray pattern, and (along with pressure) the spray droplet size and the rate of discharge. One set of nozzles for a boom may be adequate. The spray pattern and angle and the discharge rate can be varied by changing the replaceable tips or disks. Nozzle manufacturers furnish charts showing the discharge rate of the different tip or disk combinations at different spray pressures.

Spray patterns may be the flat fan, hollow cone or solid cone. The flat fan pattern is considered best for weed spraying. Both the cone and flat-fan patterns are used in insect control.

Metal, ceramic and nylon nozzles are available. Stainless steel, hardened steel or ceramic nozzles and tips or disks should be used to spray abrasive wettable powders.

Nozzle extension or droplines are available for more accurate placement of the spray, and for underleaf coverage in row-crop spraying. Special kits may be obtained for attaching nozzles on a planter for band spraying aimed at pre-emergence weed control.

The use of shields with nozzles are also used to prevent crop damage. This is accomplished by placing the spray nozzles under the shield or by covering the crop with a shield.

Application Rate

The application rate of a sprayer, the number of gallons of spray material applied per treated acre, is determined by the speed of travel, pressure, number of nozzles, and their rate of discharge. The application rate may be increased by reducing the speed of travel, increasing the spray pressure, or increasing the number of nozzles, or the size of the nozzle orifice. The rate may be decreased by increasing travel speed or decreasing pressure, and number of nozzles or orifice sizes.

Drift-Free Spraying

The problems of drift from the application of herbicides is becoming less of a problem with the development of new equipment, thickeners, and invert formulations. The marketing of these materials helps to place the herbicide on target.

New Equipment

An example of new equipment is a unique helicopter spray boom, called the "Microfoil", developed by Amchem Products, Inc. The new boom is designed to

spray uniform droplets with a minimum of hazardous fine droplets. It uses conventional carriers such as water, oil or emulsions of the two. Thickening agents or invert emulsions are not needed.

The length of the Microfoil boom can be varied from 10 to 26 feet, accomplished by bolting three- or five-foot boom sections together to achieve the desired length. The boom---its nozzles shaped like airfoils---is similar to the wing of an airplane. This design provides a minimum of air turbulence directly behind the nozzles where the droplets are formed.

Fifty-two 6-inch nozzles are mounted along a 26-foot boom, and 60 hypodermic-like needles protrude from the trailing edge of each nozzle. Therefore, the total number of orifices on a 26-foot boom amounts to no less than 3,120. From these openings, the tiny streams of liquid chemical are emitted. Properly trimmed in flight, the Microfoil produces a pattern much like a white sheet.

A new generator developed by Eron, Inc. is another example of new equipment to produce drift-free herbicide control. It generates and pumps foam simultaneously. The generator draws air or gases into the intake of a specially designed pump, introducing the foam solution into the air pocket while it is being pumped. Thus, it generates foam as the solutions pass through the series of vents, bores and ports in the pumping members, and subsequently forcibly discharges this foam at the pump outlet.

New Spray System

A new spray system called "Accutrol" is being introduced by Velsicol Chemical Corporation. The new concept is said to minimize drift, reduce the number of times required for refilling spray tanks, and increase the efficiency of the chemical being applied.

The spray system has two basic parts:

1. A special nozzles
2. A spray adjuvant (additive)

The nozzle is constructed to draw in air and mixes the air with the spray mix. It expands the spray mix by adding three to four parts of air per one part of water.

The adjuvant added to the mix holds the air within the spray droplets after they leave the nozzle. It forms a milky mixture of air and water, resembling foam, but it is referred to as an "air emulsion".

The application of large droplets under a conventional system would not provide maximum coverage, because they do not fall close together. The additive used with the mixture overcomes this problem by causing the droplets to spread over the surface of the leaf, to stick to the target plant, and to penetrate the waxy surface of the plant. The whiteness and lasting quality of the spray allows the applicator to see where he has sprayed and to control the application more accurately. It minimizes skips and reduces excessive spray usage.

Invert Formulation

The invert emulsion system is based on water-in-oil. The conventional system applied an oil and water emulsion by dispursing an oil-in-water spray. Each particle dispursed has water surrounding oil. With the invert emulsion, the oil surrounds the water. This helps eliminate evaporation, and aids the droplet in holding its shape and size during the flight from the spray boom to the weed surface. Also, the controlled droplet size serves to overcome drift caused by wind.

The formation of an invert emulsion is achieved by mixing water and special formulated herbicides drawn from two separate tanks into a special mixing chamber. It produces a thick invert emulsion that can be used in systems adaptable to both air and ground application equipment. Examples of spray systems to produce invert emulsions are the Visko-Rhap Spray System by Rhodia, Inc., and the Stule Bifluid System by Stule Chemical Company.

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Step 5. To determine amount applied per acre, divide 160 (square rods per acre) by the amount used or measured in Step 4. Example, applying 1/2 gallon to the measured area (one square rod) would mean applying 80 gallons per acre. Applying one gallon to the area would mean 160 gallons per acre.

Step 6. Determine amount of chemical to add to tank.

Calibrating for Band Spraying

1. Measure off known distance (300 ft.).

2. Determine amount of water used to spray known area.

3. Formula to calculate gallons per acre:

$$\frac{43560 \times \text{Gals. Used}}{\text{Distance x band width x No. of bands}} = \text{Gals./Acre}$$

Example: One gal. of water used to spray 300 ft. using 2 nozzles spraying 12 inch bands.

$$\frac{43560 \times 1 \text{ Gal. Used}}{300' \times 1' \times 2 \text{ bands}} = 72.6 \text{ Gal./Acre}$$

Determining Amount for Band Application

$$\frac{\text{Band Width (inches) x Rate for Overall Treatment}}{\text{Inches Between Nozzles}} = \text{Chemical Needed per Acre}$$

Example:

20 lbs./acre applied in 14 inch band spaced 40 inches apart.

$$\frac{14 \text{ inches}}{40 \text{ inches}} \times 20 \text{ lbs./acre} = 7 \text{ lbs. needed per acre applied in bands}$$

Calibrating for Granular Application

1. Collect granules from one delivery tube while driving 1000 feet at speed desired.

2. Tap measuring jar (graduated in fluid ounces) gently to settle granules when taking a reading.

3. Multiply the width of the bank (in inches) by the factor in table below opposite the broadcast rate per acre.

Pounds per Acre to be applied	Factor
1 lb.	0.0426
2 lbs.	0.0852
5 lbs.	0.2130
10 lbs.	0.426
20 lbs.	0.852
25 lbs.	1.065
40 lbs.	1.704
50 lbs.	2.130

Example: To apply 2 lbs. per acre in a 20 inch band each tube should deliver 1.7 fluid ounces in 1000 feet.

20 inch band x .0852 = 1.7 oz.

Adjust applicator so each tube delivers proper amount.

TANK-MIXING AGRICULTURAL CHEMICALS

The practice of tank-mixing agricultural chemicals is stirring up interest among many chemical users. They find it saves time, money, labor and trips across the field. But tank-mixing can also stir up such problems as government regulations, timing and rate of application and the compatability of the chemicals to be mixed.

Registering mixtures of previously cleared pesticides was fairly easy in the past. Now the Environmental Protection Agency (EPA) requires a full set of data on each mixture, as though the mixture were a completely new pesticide. In many instances the cost of registering chemical mixtures will be prohibitive.

The mixing of pesticides as tank mixtures should not be practiced by applicators if the pesticide label does not state how the pesticide can be applied in combination with other materials. Users can apply on-the-farm mixtures although the manufacturer does not register or label the combination. However, the user must assume responsibility that food and feed will be free of illegal residues.

The important factors to remember when making tank mixtures are the application requirements of each chemical and their compatibility. One of the biggest problems in tank-mixing is the failure of components to remain uniformly dispersed in the solution. Some of the causes for this are inadequate agitation, insufficient spray volume and lack of a stable emulsifier.

Wettable powders and water dispersable liquids require thorough agitation to keep them dispersed. Mechanical and hydraulic jet, or sprayer agitation, is better than bypass agitation. Suspensions also require about one to two gallons of spray carrier per pound of product to maintain good dispersion.

The compatibility of pesticides refers to the chemical, physical and phytotoxicity properties, and how well they will mix. If materials mixed together remain suspended, or are easily re-suspended, then they are physically compatible and can be used with good agitation. Certain solvents and emulsifying agents may change the compatibility of some chemicals. Weather conditions may affect phytotoxicity. Mixing procedures also can make a difference between a satisfactory or unsatisfactory blend.

Following the correct procedures in tank-mixing pesticides can be helpful in receiving optimum response from them. Never put a pesticide in an empty tank. Always partially fill the tank with the carrier before adding the pesticide. Wettable powders should be mixed with water to form a slurry before they are added to a spray tank. When mixing wettable powders and emulsifiable concentrates, add the wettable powder in slurry form first. If a compatibility agent is used to help suspend the mixture, it should be added before the pesticide. Such agents are usually added at the rate of one to three pints per 100 gallons of spray volume.

To determine the compatibility of certain pesticides, always think small and check them in small quantities before mixing them in a spray tank. One testing procedure you may use would be to place one pint of carrier in each of two quart containers. Add one-third teaspoon of compatibility agent (three pints per 100 gallons) to one container marked "A". Mark the other container "B".

Add the proper amount of each pesticide to be mixed to each container. Close the containers and mix by shaking thoroughly. Observe the mixtures immediately after shaking and again after 30 minutes. Compare container "A" with container "B" to determine the value of adding the compatibility agent. If the mixtures remain suspended, or if they are easily re-suspended, mixing is possible with good agitation.

If the mixture in container "B" separates or precipitates out, but stays suspended in container "A", then the added agent may solve the compatibility problem.

You may want to repeat the test to determine the optimum amount of compatibility agent needed.

CALIBRATION

1. Determine number of acres

   a. $$\frac{\text{Swath x Distance Traveled}}{\text{Sq. ft. per acre}} = \frac{\text{Swath x Distance}}{\text{43,560 sq. ft.}}$$

   $$\frac{\text{20 ft. x 1/2 mi. (2640 ft.)}}{\text{43,560 sq. ft.}} = 1.2 \text{ acres}$$

   b. $$\frac{\text{Length x Width}}{\text{Sq. ft. per acre}} = \text{Area treated}$$

   $$\frac{\text{435.6 ft. x 100 ft.}}{\text{43,560}} = 1 \text{ acre treated}$$

2. Determine amount of chemical mixture per acre

   a. 20 ft. swath for 1089 ft.
   Applied 10 gal. chemical mixture

   $$\frac{\text{Swath (20 ft.) x Distance (1089 ft.)}}{\text{Sq. ft. per acre}} = \frac{\text{21,780 sq. ft.}}{\text{43.560 sq. ft.}}$$

   1/2 acre treated with 10 gal. chemical mixture

   10 gal. ÷ .5 acres = 20 gal. per acre

   Also, there are 2 (21,780 sq. ft.) in 1 acre
   2 x 10 gal. = 20 gal. per acre

   b. Treating a 1/4 acre area. Used 6 gal. of chemical mixture
   6 gal. divided by .25 acre = 24 gal. per acre
   4 (1/4 acres) per acre
   6 gal. x 4 = 24 gal. per acre

3. Number of acres per tankful

   a. Determine number of gallons per acre. Gallons per tankful divided by gallons applied per acre = acres per tank.
   400 gal. tank ÷ 20 gal. per acre = 20 acres/tank

4. Determine how much chemical per tankful. Number of acres covered per tankful x rate of chemical applied per acre.
   20 acres per tankful x 2 lbs./acre = 40 lbs./tank

5. Determine number of gallons of chemical per tank. Number of lbs. per tank divided by lbs. per gallon of chemical (active ingredients).
   40 lbs. per tank ÷ 4 lbs./gal. = 10 gal. chemical

6. Preparing dilute spray from a liquid concentration

   a. How much concentrated material needed to make a certain per cent dilution.

   $$\frac{\text{0.25\% solution x 50 gal. x 8.3 lbs./gal.}}{\text{100\% x 2 lbs./gal.}}$$

$$\frac{.0025 \times 50 \times 8.3}{1.00 \times 2} = 0.52 \text{ gal. of concentrate}$$

b. 5% solution - 200 gal. of mixture with 4 lb/gal. herbicide

$$\frac{.05 \times 200 \text{ gal.} \times 8.3 \text{ lbs/gal.}}{1.00 \times 4} = \frac{83}{4} \text{ or } 20\ 3/4 \text{ gal.}$$

c. Per cent solution with 10 gal. herbicide (4 lbs/gal.) in 200 gal.,

$$\frac{10 \text{ gal.} \times 4 \text{ lbs./gal.}}{200 \text{ gal.} \times 8.3 \text{ lbs./gal.}} = .024 \text{ or } 2.4\% \text{ solution}$$

7. Preparing dilute spray from a solid concentrate.

a. 5% solution in 200 gal. with 80% wettable powder.

$$\frac{.05 \times 200 \text{ gal.} \times 8.3 \text{ lbs./gal.}}{.80} = 103.75 \text{ lbs. (80\% WP)}$$

8. Treating water with chemical.

a. How much chemical is needed to treat an area of water 200' x 500' at a concentration of 2ppm at a depth of 1 foot.

200' x 500' x 1' = 100,000 cu. ft.
100,000 cu. ft. x 62.4 lbs./cu.ft. = 6,240,000 lbs.
2 lbs./million x 6.24 million = 12.48 lbs. chemical

b. How much chemical is needed to treat a pond 100 feet long, 40 feet wide, 3 feet deep at 2 ppm with 50% chemical concentration

100' x 40' x 3' = 12,000 cu. ft.
12,000 cu. ft. x 62.4 lbs./cu.ft. = 750,000 lbs.
750,000 lbs. .75 million
1 lb. active material divided by .50 = 2 lbs. (50% chemical)
2 parts x 2 lbs. - 4 lbs. x .75 = 3.0 lbs. needed to get 2ppm from 50% material

9. Velocity of flowing water

Cu. ft. per second = Aver. width in ft. x depth in ft. x aver. velocity in feet per sec.

$$\text{Velocity} = \frac{500 \text{ feet}}{50 \text{ sec.}} = 10 \text{ feet per sec.}$$

10. How much chemical should be applied to a gallon of water when treating a small area with a hand sprayer

1 gallon	Chemical		2 lbs. per acre
4 quarts	4 lbs./gal.	=	1/2 gal chemical
8 pints	1/2 gal.		128 tbl. ÷ 43,560 sq. ft./acre
16 cups	2 qts.		= .003 tbl./sq. ft.
256 tablespoons	4 pts.		
	8 cups		
	128 tablespoons		

Area treated - 1000 sq. ft. x .003 tbl./sq. ft. = 3 tbl.
1000 sq. ft. (43 per acre) = 128 ÷ 43 = 3 tbl./gal.

CONVERSION TABLES

Weights and Measures

1 teaspoon	5 cc
3 teaspoons	1 tablespoon
1 tablespoon	15 cc
16 tablespoons	1 cup
2 cups	1 pint
1 pint	474 cc
1 gallon	768 teaspoons
1 gallon	3785 cc
1 fluid ounce	29.5 cc
2 tablespoons	1 fluid ounce
1 pint	16 fluid oz.
1 pound	454 grams
1 pound	1 pt. (water)
1 square rod	272.3 sq. ft. (16½' x 16½')
43,560 sq. ft.	1 acre
160 sq. rods	1 acre
320 rods	1 mile

Nozzle Discharge Per 100 sq. ft.		Amount of Spray Delivered per Acre
½ pint	=	27 gals.
1 pint	=	55 gals.
1½ pints	=	82 gals.
1 quart	=	110 gals.
2 quarts	=	220 gals.
4 quarts (1 gal.)	=	440 gals.

Nozzle Discharge Per 1 sq. rod	Rate in Gals./Acre
1/4 pint	5.0 gals.
3/8 pint	7.4 gals.
1/2 pint	10.0 gals.
5/8 pint	12.5 gals.
3/4 pint	15.0 gals.
1 pint	20.0 gals.
2 pints	40.0 gals.
8 pints (1 gal.)	160.0 gals.

PINTS OF COMMERCIAL MATERIAL PER ACRE TO GIVE DIFFERENT RATES PER ACRE

Active Ingredient per Gallon lbs.	Pints of Material per Acre to give the Following lbs. Active Ingredient					
	1/4	1/2	3/4	1	1 1/2	2
2.00	1	2	3	4	6	8
2.64	3/4	1 1/2	2 1/4	3	4 1/2	6
3.00	2/3	1 1/3	2	2 2/3	4	5 1/3
3.34	3/5	1 1/5	1 4/5	2 2/5	3 3/5	4 4/5
4.00	1/2	1	1 1/2	2	3	4
6.00	1/3	2/3	1	1 1/3	2	2 2/3

UNITS OF MEASURE
For Aquatic Weed Control Applications

1 acre contains 43,560 square feet
1 acre-foot is an acre of water 1 foot deep
1 acre-foot of water contains 328,012 gallons
1 acre-foot of water weights 2,722, 500 pounds
2 7/10 pounds of chemical per acre foot = 1 part per million
1 cubic foot of water weighs approximately 62 1/2 pounds
1 cubic foot contains 7 1/2 gallons
1 gallon of water weighs approximately 8 1/3 pounds
1 quart of water weighs about 2 pounds
1 pint of water weighs about 1 pound
1 cup of water weighs about 1/2 pound

CHEMICAL REQUIRED PER ACRE FOOT TO GIVE A DEFINITE CONCENTRATION IN POND WATER

Percent Active Ingredient	Amount per Acre-Foot for Different Concentrations			
	0.2 ppm	0.5 ppm	1.0 ppm	4.0 ppm
	Lb.	Lb.	Lb.	Lb.
25	2.2	5.5	10.8	43.2
50	1.1	2.8	5.4	21.6
75	0.7	1.8	3.6	14.4
100	0.5	1.3	2.7	10.8

Chemical Needed for One Square Rod and 1,000 Square Feet, Applied at the Rate of One Pound of Active Material Per Acre

Liquid Material Pounds active per gallon lbs.	Square Rod cc	Square Rod Teaspoons	1000 sq. feet cc	1000 sq. feet Teaspoons
0.67	35	7.0	130	26.0
1.00	24	4.8	87	17.6
1.50	16	3.2	58	11.6
2.00	12	2.4	43	8.8
2.50	10	2.0	35	7.0
3.00	8	1.6	29	5.8
3.34	7	1.4	26	5.2
4.00	6	1.2	22	4.4
6.00	4	.8	14	2.9

Dry Material Active Ingredient	Square Rod Grams	Square Rod Ounces	1000 sq. feet Grams	1000 sq. feet Ounces
100	2.8	.09	10	.33
90	3.1	.11	12	.42
80	3.5	.12	13	.46
70	4.0	.14	15	.53
60	4.7	.16	17	.60
50	5.6	.19	21	.74
40	7.0	.24	26	.92
30	9.4	.33	35	1.23
20	14.1	.50	52	1.83
10	28.3	1.00	104	3.66
05	56.6	2.00	208	7.33

Product to Treat 1 Square Rod if the Product Contains the Following Amounts of Acid Equivalent or Active Ingredient*

Treatment rate per acre in lbs. acid equiv. or active ingredient	Liquids 2 lbs. /gal.	Liquids 3 lbs. / gal.	Liquids 4 lbs. /gal.	Liquids 6 lbs. /gal.	Powders 50% Concentration	Powders 80% Concentration
1/2	1 1/3 tsp	1 tsp	2/3 tsp	1/2 tsp	—	—
3/4	2 tsp	1 1/3 tsp	1 tsp	2/3 tsp	—	—
1	2 2/3 tsp	1 3/4 tsp	1 1/3 tsp	7/8 tsp	—	—
1 1/2	4 tsp	2 2/3 tsp	1 3/4 tsp	1 1/3 tsp	—	—
2	5 1/3 tsp	3 1/2 tsp	2 2/3 tsp	1 3/4 tsp	5 1/3 tbsp	—
4	—	—	—	—	10 1/3 tbsp	2 1/3 tbsp
6	—	—	—	—	15 2/3 tbsp	3 1/3 tbsp
8	—	—	—	—	—	4 2/3 tbsp
10	8 2/3 tbsp	6 tbsp	4 1/3 tbsp	3 tbsp	—	5 2/3 tbsp

* tsp.--teaspoonsful
tbsp.--tablespoonsful

Methods of Weed Control

Laurence O. Baker

A weed is any plant that is growing where it is not wanted and is causing economic loss. Such plants may be found in almost every situation-in crops, in water, on ranges and timberland, in lawns and gardens, in waste areas, along roadsides, and in industrial sites. Economic loss is easy to measure where loss of plants or animals is evident due to competition or poisonious principles or where increased costs are involved in controlling the undesirable plants. Some losses are more difficult to evaluate since they are indirect-the loss of irrigation water before it reaches the field, harboring insects and diseases that attack crop plants or animals, hay fever and other allergies that reduces a workers efficiency or medication to keep him going; plant control to assist in snow removal along roads, and highways, and to help in fire control around buildings.

Undesirable plants are often called noxious. Such a designation is not correct since a noxious weed is one that has been so designated by a regulatory agency. Obnoxious might be a better term and refers to those plants that have characteristics which enable them to be especially persistent and competitive because of one or more of the following properties:

1. High germination of seed under adverse conditions.
2. Rapid development of foliage in seedling stage.
3. Rapid development of an extensive root system.
4. Production of numerous seeds.
5. Dormancy of seeds.
6. Longevity of buried seed.
7. Ability to propagate vegetatively.

8. Resistance to chemicals.

9. Effective seed dispersal.

10. Resistance to grazing.

11. Drought tolerance.

All weeds can be controlled with methods available today.Continued elimination of seed production will eradicate annual and biennial plants. Preventing top growth either by cultivation or with chemicals will cause the roots of perennials to die. Under many of the present weed situations it is not economically practical to eliminate seed production or to prevent top growth. Hence in spite of tremendous advances in technology we have weed problems that are actually increasing in severity. Much of such increase is not necessary and is due to negligence on the part of land operators; however, in some cases due to the hazards of erosion and water pollution together with economic handicaps, practical control methods are not presently available.

Effective weed control and weed erradication makes use of five general weed control methods. These include prevention, physical, managerial, biological and chemical methods. All farms and ranches should make use of these methods. Prevention is the only method that works in all situations. In order to know which methods to choose one must know something about the life cycle of the weed and about the situation where control is desired.

Prevention

The most important part of any weed control plan must include an effective effort to prevent weeds from ever becoming established on the farm. This is probably the hardest weed control operation to carry out because it requires so much attention to detail. Yet it is by far the cheapest weed control operation that can be conducted. This method begins by making sure that no living weed seeds ever enter the farm. Use only clean seed,

and weed free hay and grain. Screenings are used for feed only if they have been devitalized by grinding and heating. Several of our leafy spurge infestations resulted when screenings were fed to sheep.

Weeds can also be moved around by machinery - combines, hay balers, truck beds, earth moving equipment and cultivators. Livestock also bring weeds to your farm. This might be weed seeds clinging to the hair or it can be those carried in the digestive tract. Its cheap insurance to quarantine the new animals for a few days. You can do this by holding them in a small pasture which is watched closely so that new weeds can be destroyed before they become well established.

Prevention also includes careful observation of roadsides, fence lines, ditch banks, machinery storage areas, and any other place where crops are not grown and weeds might be introduced. Timely operations eradicate them before they become established.

Infestation of approximately 1 million acres of Montana cropland presently growing perennial noxious weeds could easily have been avoided had the previous farm operators taken time to prevent their original introduction.

Prevention is the cheapest method of weed control.

Our Weed and Seed Laws are provided to help prevent weeds from spreading. However, these laws are only as effective as we make them. We must all do our part to see that these laws are used for our benefit.

Physical Methods of Weed Control

Physical methods of weed control include tillage, mowing,burning, hoeing, and rouging. Each of these practices is effective for specific purposes. Tillage is of course the most widely used and is the best way to control many weeds. Timely tillage not only kills growing weeds, but it positions seeds in the soil so that more of them will germinate and can be destroyed.

Mowing is a practical way to prevent seed production and can be used

to destroy some annual weeds and to hold perennials in check until eradication methods can be applied. Clipping is especially useful in pastures when combined with rotation grazing, fertilizing, and sald and water distribution. Certain undesirable plants in some situations can best be killed by rouging or with the hoe.

Managerial

The first plant to occupy an area of ground tends to exclude other plants. This means that crops should be given every opportunity to become established before weeds. Some plants are more competitive than others-both crops and weeds. Hence, certain weeds are more competitive with one crop than another such as green foxtail which seriously affects most row crops, but generally does little damage to small grains.

Growth habits of plants help to determine their competitive ability. Winter wheat is a good crop to use in combination with tillage and herbicides for control of Canada thistle and field bindweed, but is not nearly so effective competing with whitetop because their growth habits are so closely correlated. Vigorous alfalfa cut for hay will kill Canada thistle due to shading, but it encourages the spread of whitetop.

Crop rotation in combination with other weed control methods is very helpful in controlling many weeds.

Biological Weed Control

Biological weed control refers to the use of living organisms to control weeds. The term is used loosely to include grazing by livestock as well as more specifically to mean the use of insects and diseases. Sheep and geese have been used to control weeds in cotton and mint. Many weeds along ditch banks can be controlled by livestock. Certain fish have recently been found to show promise for control of water weeds in warmer southern waters. This too is biological control.

Weed control with insects has been demonstrated to be effective. Such control, however, is not rapid. While it might be satisfactory in pasture and range areas, control is too slow to be relied on for protecting annual crops.

Chemicals

Herbicides are one of the most useful tools for weed control, but they should never be regarded as a substitute for good farming. When used properly, herbicides can help produce bigger crops of better quality. They can reduce labor requirements, eliminate fire hazards and improve the appearance of our surroundings. To insure the proper use of weed killing chemicals they should be used only on the crop and in the manner specified on the label.

Combination of Methods

Prevention is the only method of weed control that works best along. For most economical weed control it is usually most practical to combine all methods into a total farm weed control operation. Not all methods would be involved on all fields each year, but rather suitable combination could be used.

In an effort to obtain an estimate of the timing of the "green wave", observations were made on the greening of a three-acre level bluegrass lawn on the Montana State University campus adjacent to the Weather Service climatological station. This field is exposed to full sunlight and is irrigated during the growing season. In the spring of 1972, colored pictures were taken of the field every several days. Information on phenological stages of the purple common lilac and two honeysuckle species growing in one corner of the field were made during the same period. It was determined from this information that the field changed from a predominate brown to a predominate green color at approximately the same time that 200,000 Solar-Thermal Units (STU) had accumulated. This corresponds approximately to the time when potential evapotranspiration has reached a total accumulation of about two inches(1).

Since information on only temperature and solar radiation is required to determine the accumulation of STU in the spring, a rough estimate of the average date of green wave passage can be made for those locations where both temperature and solar radiation are measured. The average date when 200,000 STU accumulate was determined for more than 100 locations in middle and high latitudes of the northern hemisphere. It was assumed that plant growth was not limited by lack of soil moisture. Also, lines of average green wave arrival were drawn only for places where minimum temperature during the coldest time of the year averages near or below 31 degrees Fahrenheit.

Since mean temperatures for the coldest month at stations in the Southern Hemisphere north of Antarctica are nearly all above freezing, no lines have been drawn in the Southern Hemisphere. This suggests that most of the land in the Southern Hemisphere could be green the entire year, given proper vegetative cover and an adequate supply of moisture. No attempt has been made to account for the many irregularities in the pattern in mountainous terrain.

The map of the geographical progression of the green wave is given in Figure 2. The estimated isopleths of dates of green wave passage make an interesting pattern. The April 15 line, for example, extends from a southern extreme of about 35 degrees north latitude in the United States and Japan to a northern extreme of about 55 degrees north latitude in western North American and western Europe. The July 15 line appears to correspond rather closely with the southern margin of the tundra zone. The tundra extends from the poleward limit of forest, northward to the southern edge of the zone of perpetual ice where practically no plant life is found.

Undoubtedly, numerous modifications of this preliminary estimate of the average advance of the green wave will have to be made as more information from ground, aircraft and satellite observations becomes available. Remote sensing information from aircraft and satellites was not utilized in constructing this map.

PHENOLOGY SATELLITE EXPERIMENT

Scientists are involved in scores of research projects designed to determine possible applications for satellite information in their particular fields. One such research project entitled "Phenology Satellite Experiment" is designed to determine possible uses of satellite data in phenology.

On July 23, 1972 the National Aeronautics and Space Administration lauched the first Earth Resources Technology Satellite (ERTS-1). The satellite is orbiting the earth from north to south at a height of about 500 miles and returns to the

(1) Caprio, J. M. "The Solar-Thermal Unit Theory in Relation to Plant Development and Potential Evapotranspiration", Circular 251, Montana Agricultural Experiment Station, Bozeman, 10 pages, March 1971.

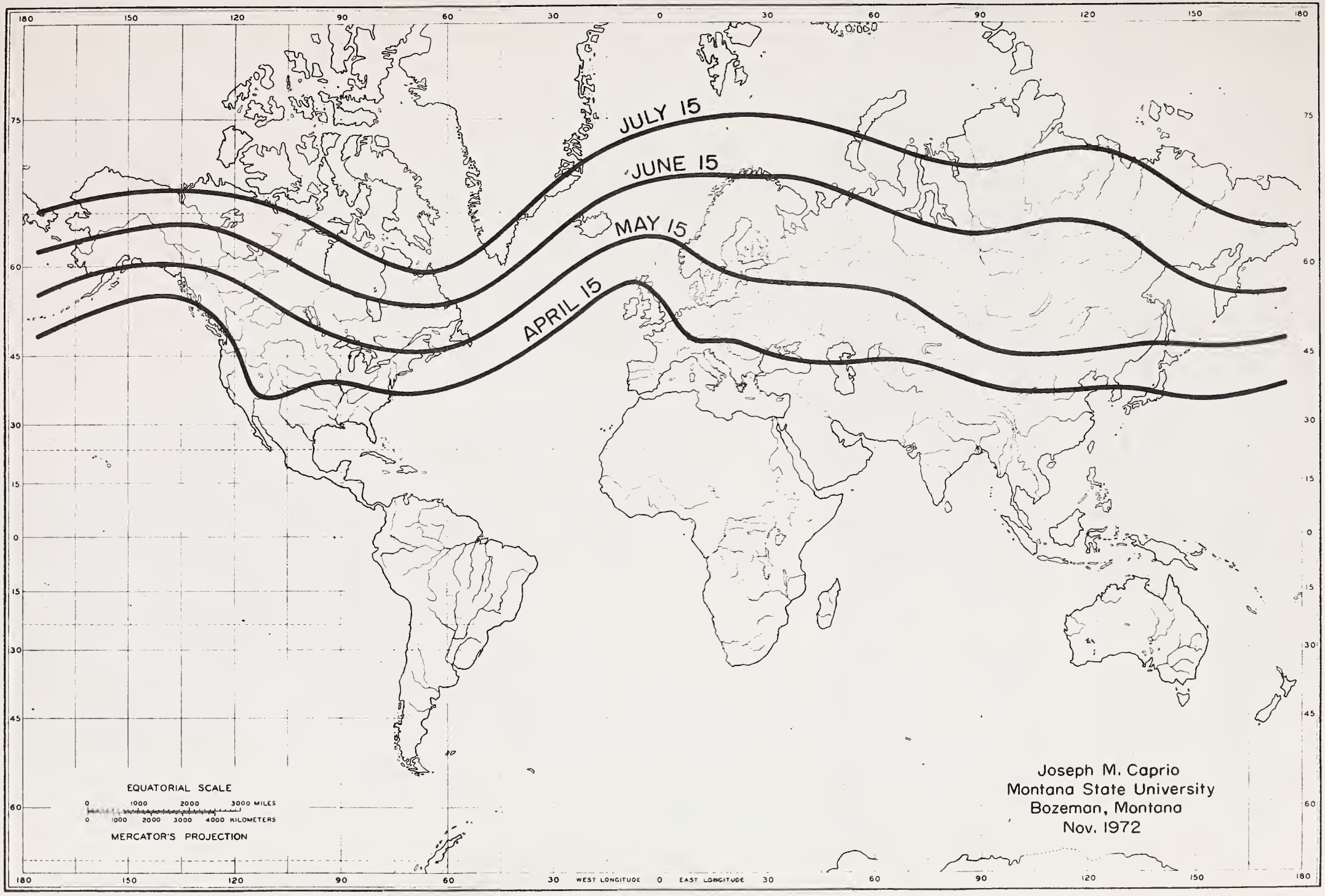
JULY 15
JUNE 15
MAY 15
APRIL 15
EQUATORIAL SCALE
0 1000 2000 3000 MILES
0 1000 2000 3000 4000 KILOMETERS
MERCATOR'S PROJECTION
Joseph M. Caprio
Montana State University
Bozeman, Montana
Nov. 1972
180 150 120 90 60 30 WEST LONGITUDE 0 EAST LONGITUDE 30 60 90 120 150 180
75 60 45 30 15 0 15 30 45 60

Figure 2. Average Date of Green Wave Passage (After Preliminary Model).

same path every 18 days. It is an experimental spacecraft, intended to demonstrate the usefulness of repeated satellite observations of the earth's surface. It will take photographs and relay spectral (surface color) information back to earth for at least a year.

One of the objectives of the Phenology Satellite Experiment is to learn more about the polar advance of the green wave of new vegetative growth in the spring. Numerous agricultural experiment stations throughout the country are participating in this project under sponsorship of the National Aeronautics and Space Administration.

The timing of the green wave will vary from year to year due to annual differences in weather conditions in a manner similar to annual fluctuations of such phenological events as the blooming of lilacs and honeysuckle. It will be possible in the future to determine the average date of green wave passage at a given point on the earth's surface if records of the greening of the vegetation are kept at the site for a number of years. Thus, by utilizing ground observations or possibly aircraft and satellite data, accurate maps of the average date of green wave passage for given geographical areas may be developed. This information on the green wave could be very useful for resource management agencies and others concerned with managing the extensive farm and forest areas of the nation.